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Memoirs of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

Vol. XXX. No. 2.

REPORTS ON AN EXPLORATION OFF THE WEST COASTS OF MEXICO, CENTRAL AND SOUTH AMERICA, AND OFF THE GALAPAGOS ISLANDS, IN CHARGE OF ALEXANDER AGASSIZ, BY THE U. S. FISH COMMISSION STEAMER "ALBATROSS," DURING 1891, LIEUT. COMMANDER Z. L. TANNER, U. S. N., COMMANDING.

XXXI.

THE RADIATING ORGANS OF THE DEEP SEA FISHES.

By ROBERT VON LENDENFELD.

WITH AN APPENDIX ON THE STRUCTURE OF THE BUD-LIKE ORGANS OF MALTHOPSIS SPINULOSA GARMAN.

By EMANUEL TROJAN.

WITH ELEVEN PLATES,

AND A CHART OF THE ROUTE.

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The following Publications of the Museum contain Reports on the Dredging Operations in charge of Alexander Agassiz, of the U. S. Fish Commission Steamer "Albatross," during 1899 and 1900, Commander Jefferson F. Moser, U. S. N., Commanding.

I. A. Agassiz. Preliminary Report and List of Stations. With Remarks on the Deep-Sea Deposits by Sir John Murray. Mem. M. C. Z., Vol. XXVI. No. 1. January, 1902. 114 pp. 21 Charts.

II. A. G. Mayer. Some Species of Partula from Tahiti. A Study in Variation. Mem. M. C. Z., Vol. XXVI. No. 2. January, 1902. 21 pp. 1 Plate.

III. A. Agassiz and A. G. Mayer. Medusæ. Mem. M. C. Z., Vol. XXVI. No. 3. January, 1902. 40 pp. 13 Plates, 1 Chart.

IV. A. Agassiz. The Coral Reefs of the Tropical Pacific. Mem. M. C. Z., Vol. XXVIII. February, 1903. 33, 410 pp. 238 Plates.

V. C. R. Eastman. Sharks' Teeth and Cetacean Bones from the Red Clay of the Tropical Pacific. Mem. M. C. Z., Vol. XXVI. No. 4. June, 1903. 14 pp. 3 Plates.

VI. W. E. Hoyle. Cephalopoda. Bull. M. C. Z., Vol. XLIII. No. 1. March, 1904. 71 pp. 12 Plates.

VII. H. Ludwig. Asteroidea. Mem. M. C. Z., Vol. XXXII. July, 1905. 12, 292 pp. 35 Plates, 1 Chart.

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THE RADIATING ORGANS OF THE DEEP SEA FISHES.

1. INTRODUCTION.

The fishes collected by the "Albatross" in 1891 have been carefully described by Mr. Samuel Garman ('99). A considerable number of them possess radiating, or, as they were formerly termed, phosphorescent organs. Mr. Alexander Agassiz was so kind as to place many of these at my disposal and to permit me to study the minute structure of their radiating parts. For this valuable material and his subsequent furtherance of the work, I express my sincerest thanks. The results of the examination of these organs are detailed in this paper.

The fishes sent to me belong to the following species: —

Argyropelecus lychnus Garman.
Bassozetus nasus Garman.
Chauliodus barbatus Garman.
Cyclothone acclinidens Garman.
Halosaurus radiatus Garman.
Idiacanthus antrostomus Gilbert.
Ipnops agassizii Garman.
Leuciocorus lusciosus Garman.
Lychnopoles argenteolus Garman.
Macrurus canus Garman.
Malthopsis spinulosa Garman.
Mixonus caudalis Garman.
Myctophum aurolaternatum Garman.
Sternoptyx obscura Garman.
Stomias hexagonatus Garman.

All, with the exception of *Mixonus caudalis*, were sufficiently preserved in alcohol to allow of the examination of their radiating organs.

Since Garman did not pay particular attention to these organs, his statements concerning their arrangement and number are not always sufficient. This applies to the figures even more than to the descriptions. For this reason the entire fishes are here figured again.

The minute structure of the organs was studied by means of paraffin and celloidin sections. Various stains were employed. Van Gieson's haematoxylin-picric acid-fuchsin gave the best results. Most of the sections

photographs, and drawings were made by Mr. E. Trojan while working in my laboratory. I must express my thanks for the great pains Mr. Trojan has taken with this work; and for his paper on the structure of the bud-like organs of *Malthopsis spinulosa* which I add as an appendix to this memoir.

Three types of radiating organs are represented by the fishes examined: — ocellar radiating organs, radiating discs, and tubular radiating organs.

2. DESCRIPTION OF THE RADIATING ORGANS.

(1) THE FISHES WITH OCELLAR RADIATING ORGANS.

Argyropelecus lychnus Garman.

Plate 6, Figs. 24, 25.

This species has been described by Garman ('99, p. 234, Plate J, Fig. 1, lb). The radiating organs are of considerable size, possess exceedingly brilliant reflectors and are surrounded by a layer of dark pigment, so that they are very conspicuous. There are on each side 1 anteorbital (Plate 6, Fig. 25, ao), 1 postorbital (po), 2 opercular (op), 6 branchiostegal (br), 6 pectoral (pc), 12 ventrothoracic (vt), 2 anterior lateral (al), 6 medial lateral (ml), 4 ventromedial (ve), 6 anal (a), and 4 ventrocaudal (vc), radiating organs. Besides these there also exists, according to Garman ('99, p. 234), a frontal.

The axis of all the organs lies very obliquely and nearly parallel to the surface in such a way that it is directed vertically downwards. The anteorbitals, the postorbitals, and the opercular are simple. The others are joined in longitudinal rows in which they lie side by side. The right and left ventrothoracic organs form a double row which appears as a medial crest, protruding ventrally. All the organs with the exception of the anteorbitals, in which the sheaths are absent, are similar in structure, and size, and the differences in their appearance are due chiefly to the different degrees of coalescence. This is *nil* in the three cephalic organs mentioned, and greatest in the ventrothoracics.

The organs are 2 to 3 mm. long and 1 mm. or a little more broad. Each radiating organ (Fig. 24) is composed of a slender elongated ellipsoidal proximal (A), and a narrow funnel-shaped distal part (D). These parts are

separated by a clearly marked constriction (C). The proximal oval part has in the single organs a circular transverse section throughout; in the joined organs it is not so regular. The distal funnel shaped part is in life probably a rotation paraboloid, but on account of shrinkage appears somewhat irregular in the sections (Fig. 24). In accordance with the smallness of the angle enclosed between the axis of the organ and the surface of the fish, the funnel abuts very obliquely on the latter; it is long on the inner, and very short on the outer face, a very oblique truncated cone with bulging parabolic sides.

The whole organ with the exception of the funnel mouth, which is closed by a transparent membrane, is surrounded by a thin layer of cells containing a dark brown pigment. These form an outer pigment sheath (p). Inside this lies another sheath composed of colorless, highly refractive fibres. This (r) is exceedingly thick at the proximal end of the inner, oval part of the organ and gradually thins out from here to the margin of the funnel. It is most highly developed in the joined ventrothoracic organs, where it forms a continuous mass. The fibres composing this layer are parallel, pretty stout, lie close together, and extend longitudinally from the proximal apex of the elliptical part to the distal margin of the funnel. In life these fibres probably follow the curvature of the layer which they form, but are not otherwise bent. In sections (Fig. 24) they often form zigzag lines in the distal thin part of the reflecting layer (B). This also is probably attributable to shrinkage.

In the tissue occupying the proximal and central part of the interior space surrounded by the fibrous layer three regions can be distinguished: an inner (g), a middle (l), and an outer (s). The limits between these regions are well defined. The inner region extends to the constriction between the oval and conic part of the organ and there ends with a slightly convex surface vertical to the axis. In the joined organs, particularly in the ventrothoracics, the inner regions of adjacent organs coalesce to form extensive cellular masses surrounded by common fibre and pigment sheaths.

The tissue occupying the inner region (g) has in all sections, whatever their direction may be, an alveolar or reticulate appearance; in the alveoles or meshes residual masses of protoplasm and small spherical nuclei, both readily staining with haematoxylin, are clearly visible. Very rarely a slight indication of an arrangement of the meshes of this network in rows is met with. The meshes or alveoles are about 20 μ wide. Occasionally one sees

a capillary vessel traversing this tissue but these appear to be rare. The residual protoplasmatic masses and the nuclei appear attached to the strands of the network, or the walls of the alveoles. The structure of this tissue is pretty much the same throughout the whole region it occupies.

The middle region (l) occupies the lower portion of the conic part of the organ. Its limit towards the inner region is, as we have seen, concave and smooth. The outer limit is not well defined, the middle region gradually passing into the outer, which is composed of small digitate papillae lying close together. The middle region is composed of cells, which, in longitudinal, axial sections (Plate 6, Fig. 24) appear transversely arranged and mostly long, slender, and spindle-shaped. On the whole this tissue takes stains, particularly haematoxylin, somewhat less readily than the parts below and above it. It is traversed by numerous capillary vessels. Whether the cells here in the proximal part of the middle region are really spindle-shaped or lamellar, overlying each other like the cells in the epithelium of the human skin, could not be decided. Distally, towards the papillae, the arrangement of these cells becomes less regular and the cells themselves become smaller, the nuclei lying much closer together. The papillae forming the outer region are composed of similar cells; these are often much curved, but also on the whole arranged paratangentially. This outer region is poorer in blood vessels than the inner.

The distal part of the cone beyond the outer region contains only a few doubtful traces of cells and chiefly consists of a gelatinous substance, which takes haematoxylin and some other stains pretty readily and which in some sections exhibits a very strongly marked stratification, the layers being slightly oblique to the outer surface.

The structure of the radiating organs in the genus Argyropelecus was first examined in *A. hemigymnus* by Ussow ('79, pp. 103–104, Plate 1, Fig. 5). According to his description these organs of *A. hemigymnus* are similar in appearance and arrangement to those of *A. lychnus* described above. Ussow states that the internal tissue of the inner region is composed of glandular cells supported by a scaffolding (Gerüst) of connective tissue.

Leydig ('81, pp. 26–39, Plate 1, Fig. 5; Plate 1, Figs. 13, 14; Plate 3, Figs. 19, 20, Plate 4, Figs. 22–27; Plate 5, Figs. 28–31; Plate 6, Fig. 35) has described these organs in the same species. So far as their arrangement and appearance are concerned, this description accords with that of Ussow. The anteorbital organ is innervated by branches of the nervus trigeminus, which

enter it at various points. The stoutest nerve branch enters the organ at the constriction between the oval and conic parts. The cells composing the inner region are described as arranged in columns. Leydig suggests (l. c., p. 38) that the fish may swim on its side like a pleuronectid, and not vertically. He supports this view by stating that the pigment is not equally developed on the right and left side and by quoting a statement of Valenciennes to the effect that the similar *Sternoptyx hermanni* "flotait renversé sur le côte." Garman (l. c.) does not mention the occurrence of any difference in the coloration of the two sides in *A. lychnus*, nor have I noticed it. However the case may be with *A. hemigymnus* I do not think it likely that *A. lychnus* swims on its side. In a previous paper ('87, pp. 303–307) I have described the radiating organs of *A. hemigymnus* and other fishes, in which they have a similar structure. The fibrous layer in the organs of *A. hemigymnus* was found to contain parallel and longitudinally arranged fibres of considerable length; so there is no difference between these species and *A. lychnus* in this respect. The statement there made that the inner region is composed of tubes *lined* with glandular cells does not apply to *A. lychnus*, where such tubes could not be made out; there is hardly even a trace of the columnar arrangement described by Leydig.

Brandes ('99, p. 470), who also described *A. hemigymnus*, says that the anteorbital organs are connected with muscles and can be moved about at will so as to throw their radiation in any direction the fish may choose. This statement has been contradicted by Handrick ('01, p. 54). The fibre sheath consists of long and slender tissue cells containing guanin and lime. The tissue of the inner region is, according to Brandes ('99, p. 484), composed of roundish gland cells and is without efferent ducts. These cells produce a secretion which, according to Brandes, disintegrates chemically and thereby emits light. The light passes the middle region, considered by him as a biconcave lens, and illuminates the gelatinous mass which occupies the outer region, and which is backed by the inner face of the distal part of the reflecting fibre layer. Thus the luminosity would be visible chiefly from points at the side of the fish.

Chiarini ('00, pp. 7–10, Figs. 1, 4, 5) has likewise studied the organs in *A. hemigymnus*. He reproduces a figure (1) of an axial longitudinal section of one of them, which — apart from its being upside-down — closely corresponds to the figure of a similar section of the anterior lateral organ in *A. lychnus* here given (Plate 6, Fig. 24). According to Chiarini the pigment

layer of the organs of *A. hemigymnus* is not quite continuous, but interrupted by longitudinal lines free from pigment. The fibre layer is exceedingly thick. The internal tissue has no special covering membrane and is in immediate contact with the fibre layer. The inner region of the internal tissue is composed of polygonal cells. Each contains granules and one or two nuclei. These cells are not regularly arranged; there is, however, an indication of a concentric stratification near the outer limit (towards the middle region). The cells of this inner region are supported by reticulate connective tissue. The middle region is composed of cells with a polygonal contour, arranged transversely. In the outer region the cells are arranged more or less longitudinally. Also in this middle region a supporting reticulation of connective tissue is met with. The distal portion of the cone is occupied by gelatinous tissue.

Handrick ('01) has published a detailed account of the nervous system and the radiating organs of the same species. He appears to have been unacquainted with Chiarini's paper cited above. Handrick ('01, p 58, 59) carefully worked out the innervation for most of the radiating organs ('01, pp. 58, 59). The anteorbital is — as Leydig had previously stated (see p. 173) — innervated by the trigemius, the postorbital, opercular, and branchiostegal by the facialis, the others by spinal nerves. The radiating organs are not movable relative to the body (*versus* Brandes, see p. 173) but the concavity of the sheath can be changed by muscular action ('01, p. 54). A few very elongated nuclei belonging to the fibre cells were observed in the inner sheath. The tissue of the inner region, the "Leuchtkörper," is very minutely described ('01, p. 55). It is not in direct contact with the fibre sheath (as stated by Chiarini), but separated from it by a special membranous layer of connective tissue. From this, strands of connective tissue extend inward. These are much branched and anastomizing form a network along which nerves and blood vessels extend, and in the meshes of which large round or polyedric cells lie. The columnar arrangement described by Leydig ('81, p. 31, see p. 173) cannot be made out. Handrick ('01, p. 56) gives a detailed description of the internal structure of these cells and distinguishes two varieties of them. According to him they always have only one nucleus, not sometimes two as stated by Chiarini (see above). The tissue of the middle region is, according to Handrick ('01, p. 57), also supported by a reticulation of connective tissue. He considers the cells forming its proximal portion as spindle shaped, those forming the distal por-

tion as "polygonal," meaning perhaps polyedric. The latter are, as it has been described above of *A. lychnus*, also in *A. hemigymnus*, smaller than the former. Handrick found blood vessels but no nerves in the middle region. The extent of the gelatinous tissue occupying the distal part of the cone is different in the different organs; it is absent altogether in the anteorbitals. In this region a loose network of connective tissue with large nuclei extends, the interstices being occupied by a gelatinous substance ('01, p. 58).

According to this, the latest paper on *A. hemigymnus*, the radiating organs of this fish seem to have very much the same structure as those of *A. lychnus*.

Sternoptyx obscura Garman.

Plate 6, Figs. 26, 27.

This species was described by Garman ('99, p. 232, Plate 53, Fig. 1). The radiating organs are, as in *Argyropelecus lychnus*, very conspicuous. There are on each side 2 opercular (Plate 6, Fig. 26 op), 5 branchiostegal (br), 10 ventrothoraic (vt), 3 ventral (ve), 3 anterior lateral (al), 3 posterior lateral (pl), 3 anal (a) and 4 ventrocaudal organs (vc). As in *Argyropelecus lychnus* all these groups form rows in which they lie close together. The 20 ventrothoracic organs of the two sides are joined to form a medial crest protruding from the ventral side of the fish. The inner regions of the internal parts of these organs are joined and form a continuous mass. The axes of all the organs enclose very small angles with the outer surface and thus lie nearly paratangentially. The 2 opercular of each side are oblique, directed downwards and backwards, all the others more or less vertically downwards.

Besides these organs observed by me, Garman ('99, p. 233) mentions a silvery area below the eye which he thinks may be a rudimentary suborbital radiating organ.

The structure of the organs is apparently the same as in *Argyropelecus lychnus*. In some of them, however, chiefly in the ventrothoracic organs (Plate 6, Fig. 27), the proximal part of the pigment sheath (p) is thicker and the middle and outer region together are much less extensive than in that fish. These appear here (l and s) as a rather thin, oblique, lenticular body separating the extensive gelatinous outer mass (gl) from the cellular inner region (g). Traces of stratification could also be detected in the outer region.

I have described ('87, p. 303, Plate 70, Figs. 15–24) the radiating organs of *Sternoptyx diaphana*. In that species extensive radiating organs are met with on the lips, and I think that such may also be present in *S. obscura;* but as that portion of the specimen at my disposal is somewhat injured I cannot express myself with certainty on this point. The glandular tubes as figured ('87, Plate 70, Fig. 20) in the inner coalesced regions of the ventrothoracic organs cannot be made out in *S. obscura;* in this fish they appear to consist, as in Argyropelecus, of an alveolar network containing large, roundish cells.

Lychnopoles argenteolus Garman.

Plate 7, Figs. 31–37.

This species has been described by Garman ('99, p. 244, Plate 53, Figs. 4, 4a). The radiating organs appear as spots, 700 μ in diameter, with a silvery lustre, and are pretty conspicuous. There are on each side 1 anteorbital (Plate **7**, Figs. 31, 32 ao), 1 mandibular (Figs. 32, 33 ma), 11 branchiostegal (Fig. 33 br) 9 guttural (Figs. 33 g), 2 opercular (Figs. 31, 32 op), 14 ventrothoracic (Figs. 31, 32 vt) — Garman ('99, p. 245) counts 15 of these — 19 ventromedial (Figs. 31, 32 ve), 22 anal (Figs. 31, 32 a), 11 anterior lateral (Figs. 31, 32 al), 10 mediolateral (Figs. 31, 32 ml), and 22 posterior lateral (Figs. 31, 32 pl) radiating organs. Garman ('99, p. 245) states that there are besides these two parallel rows of radiating organs on the sides of the body. In the partly injured specimen at my disposal these could not be made out.

With the exception of the anteorbital organ which is somewhat peculiar and which will be described below, all the radiating organs mentioned have the same external and internal structure. They consist, as in Argyropelecus and Sternoptyx, of two parts, a proximal and a distal. The proximal part (Plate **7**, Fig. 37 A) is approximately spherical and forms about three quarters of a sphere. The constriction (C) between the proximal and distal part is well defined but shallow, so that the "neck" of the organ has a considerable breadth. The distal part (D) appears as a broad and somewhat short rotation paraboloid, obliquely cut off where it abuts on the surface of the body. The blood vessels in the subcutaneous connective tissue surrounding the organ (b) are more numerous close to the pigment sheath than elsewhere. The pigment sheath (Plate **7**, Figs. 35, 37 p.) is stout,

dense, and of uniform thickness in the inner spherical part and the proximal portion of the outer parabolic part. Towards the surface it thins out. The reflecting layer (Figs. 35, 37 r) is about as thick as the pigment layer and composed of longitudinally arranged fibrous cells. It does not extend to the surface and terminates some distance within the margin of the pigment layer. On the inner side of the reflecting layer a conspicuous connective-tissue membrane (Figs. 35, 37 c) about as thick as the two other layers, is met with. Distally this membrane passes into the gelatinous portion of the outer region of the organ.

Three regions (Plate **7**, Fig. 37 g, l, s), can be distinguished in the tissue forming the internal part of this organ in Lychnopoles as in Argyropelecus and Sternoptyx; in Lychnopoles, however, these are built on a somewhat different plan.

From the connective-tissue membrane (Plate **7**, Figs. 35, 37 c) mentioned above membranous diverticula extend inward which join to form facets arranged radially. In the proximal spherical part of the organ these membranes are straight and each facet encloses a regular pyramidal space. Its apex lies near the centre of the sphere, and its base abuts on the connective-tissue membrane overlying the reflecting layer (Plate **7**, Fig. 37). The radial membranes (facets) do not extend quite to the axis. A somewhat irregular tubular cavity (Plate **7**, Fig. 37 cc) occupies that portion of the axial part of the organ which lies between the centre of the proximal sphere and the focus of the distal paraboloid. The margin of this tube is so well defined that it looks as if a special limiting membrane were present. Its cavity appears empty, neither blood corpuscles nor other bodies were found in it. In the pyramidal spaces enclosed by the facets, nuclei and residual protoplasmatic masses highly stainable with acid-fuchsin are met with. These adhere chiefly to the connective-tissue membrane at the base of the pyramid and to the adjoining parts of the radial membranes: the central parts of the facets (Plate **7**, Fig. 37 ci) are pretty free from them.

The facets in the distal paraboloid are not so regular as those in the proximal sphere. The inner (proximal) part of the paraboloid is occupied by pretty narrow, more or less curved facets (Plate **7**, Fig. 37, cm) extending from the sides towards the distal end of the tubular cavity above described. These facets are pyramidal, distally broad and proximally contracted. The outer (distal) part of the paraboloid is occupied by regular

straight, prismatic facets (Plate **7**, Fig. 37 co) which are parallel to the axis of the organ; they are rounded off distally and drawn out proximally to points converging towards the distal end of the tubular cavity. The distal ends of these facets lie in a surface convex outwardly and *in toto* vertical to the axis of the whole organ. The triangular space outside these facets, between them and the surface, is occupied by gelatinous tissue (gl).

The small curved facets and the proximal portions of the large straight ones which together occupy the inner part of the paraboloid and form the middle region of the organ (Plate **7**, Fig. 37) are clothed with a single layer of cylindrical cells which form a kind of simple epithelium (Plate **7**, Fig. 36). These cells take up the greater part of the space within the facet and only leave an exceedingly narrow central canal (Plate **7**, Fig. 36 cn) free. This canal extends longitudinally in the axis of the facet towards the tubular space in the interior of the organ. Probably it opens into it, as I have seen many indications of such a connection, but I am not certain about it. The cylindrical cells forming the epithelial clothing of these facets and surrounding the central canal are composed of two kinds of protoplasm. The proximal three quarters of each cell (lying next the canal) (Plate **7**, Fig. 36 ph) are transparent and only slightly stainable; the distal quarter (lying next the facet wall) (Plate **7**, Fig. 36 pt) is granular and takes stains very readily, so that it appears dark and not transparent in the stained sections. In this highly stainable, basal portion of the cell the nucleus (nu) is situated.

It is probable that the facets of the proximal spherical part of the organ described above contain the same kind of tissue, but the condition of the material does not allow of this being definitely determined.

The tissue occupying the distal parts of the large straight cylindrical facets and forming the outer region of the organ (Plate **7**, Fig. 37 s) is of an entirely different character. Here we find elongated, slender cells, which are rather indifferent to most stains, but become intensely yellow after treatment with picric acid. In the distal basal part of each of these facets these cells are very slender, spindle-shaped, and arranged longitudinally, parallel to the axis of the facet (Plate **7**, Fig. 34 sp). Towards the proximal part they become stouter and shorter and here they often appear club-shaped. The cells appear to rise from the walls of the facet. Those joined to the terminal face of the facet arise more or less vertically; those joined to the sides arise very obliquely and extend nearly parallel to the facet wall to which they are attached. The cells in the distal part of the

facets are nearly straight throughout the whole of their length. As we approach the proximal part of the facet we find these cells curving away more and more from the walls of the facet so that their free ends come to lie more or less obliquely (Plate **7**, Fig. 34 sc). Finally they are situated nearly transversely, the cells arising from the different sides interlacing axially.

In the sections one often finds a circular structure of considerable size (Plate **7**, Figs. 34, 35 o) in the centre of the facet. Sometimes it appears as an empty space, and is perfectly colorless and structureless; sometimes it has — in sections stained with acid-fuchsin — a bright red color and then one occasionally notices traces of a granular structure within it. The tissue surrounding the circle often shows a fine radial structure (Plate **7**, Figs. 34, 35). I have not been able to ascertain the real nature of these circles and their coronas with any degree of certainty. The circles seem to be the expression of spherical spaces lying between the cells, and the radial structure surrounding them might be due to the fact that the slender inner terminations of the spindle cells abut vertically on this sphere.

The organ is rich in blood vessels. These follow the facet walls and can often be traced for a considerable distance.

The gelatinous tissue (Plate **7**, Figs. 34, 37 gl) mentioned above is composed of a gelatinous ground substance traversed in all directions by exceedingly slender spindle cells. It passes into the connective-tissue membrane overlying the reflecting layer. A thick granular lamella or cushion (Plate **7**, Fig. 37 gr) underlies this gelatinous tissue and separates it proximally from the reflecting, and distally, where this is absent, from the pigment layer.

As mentioned above, the anteorbital radiating organ differs in some respects from the others. It appears to be much larger and measures 1.5 mm. in diameter. Closer examination shows that it is a duplex organ composed of two, each similar to the other radiating organs of the fish. These two organs point different ways and are enclosed in a common pigment sheath which has the shape of a curved tube open at both ends. The two orifices of this tube lie in the surface; one is oblique, directed upwards and forwards towards the eye, the other vertical, directed straight downwards. The spherical parts (inner regions) of the two organs occupy its central, the paraboloidal parts (middle and outer regions) and the gelatinous and granular tissue the terminal portions of the tube. These two joined organs throw their radiation in different directions, one into the field of

vision and the other downward, neither inward nor backward, as Garman ('99, p. 245), who also noticed that this organ differs in structure from the others, seems to think.

Cyclothone acclinidens Garman.

Plate 6, Figs. 28-30.

This species has been described by Garman ('99, p. 247, Plate **J**, Fig. 4), whose statements concerning the radiating organs are, on the whole, in accordance with my observations; in his figure (4), however, 2 opercular and 5 posterior lateral organs are drawn which do not exist and which Garman himself does not mention in his description. The other organs are represented in the figure as lateral whilst they are in reality situated on the ventral side of the body.

The radiating organs are very small, only 700 μ in diameter, and are destitute of reflectors. On account of their insignificant size and want of lustre, they are far from conspicuous and not easy to make out. There are on each side 10 branchiostegal (Plate **6**, Fig. 29 br), — Garman ('99, p. 247) gives their number as 13 — 13 ventrothoracic (Figs. 28, 29 vt), 3 ventromedial (Figs. 28, 29 ve), and 16 ventroanal (Figs. 28, 29 a) radiating organs.

All the organs seem to have the same structure. They are approximately spherical and enclosed in a pigment sheath which forms over three quarters of a sphere and encloses them on all sides except where they abut on the surface of the fish. A straight line drawn through the centre of the sphere and the centre of the more or less circular superficial orifice of the pigment sheath is vertical to the surface of the body.

The pigment sheath (Plate **6**, Fig. 30 p) is composed of cells containing dark brown pigment granules. It is very stout. Its inner surface is pretty smooth, the outer covered with irregular protuberances. Within the pigment sheath a connective-tissue membrane (Plate **6**, Fig. 30 c) is met with. Near the surface this splits up into two membranes, one covering the mass of radiating cells proper on the outer side (Plate **6**, Fig. 30 cr) the other forming a thick superficial cell layer (Plate **6**, Fig. 30, l and cd).

Three zones can be distinguished in the organ: an inner, occupying about three quarters of the whole sphere, an intermediate, and an outer.

The inner zone is composed of a mass of large polyedrical cells and enclosed in a connective-tissue capsule. The part of this capsule which covers the radiating cell mass inwardly and laterally and separates it from

the pigment sheath (Plate 6, Fig. 30 c) is the connective-tissue membrane mentioned above. The part of the capsule covering the cell mass outwardly and separating it from the intermediate zone (Plate 6, Fig. 30 cr) is the innermost of the two layers into which the connective-tissue membrane splits up near the surface. From this outward part of the covering membrane lying near the surface diverticles extend inwards dividing the outer two thirds of the cell mass into somewhat irregularly pyramidal facets, the (distal) bases of which are closed by the outer capsule membrane whilst the (proximal) apices are wide and open. The innermost part of the cell mass is not thus divided into facets. The facets are occupied by large polyedrical cells (Plate 6, Fig. 30 r) arranged in radial rows. Each cell contains a large and conspicuous spherical nucleus; its protoplasm is readily stainable with acid-fuchsin. The same cells are met with on the inward side of the organ, but here they form layers parallel to the surface of the organ and are not arranged in radial rows. In the interior, a little below the centre, a mass of much smaller cells (Plate 6, Fig. 30 m) is observed. These look like closely packed blood corpuscles. Possibly there exists here a blood sinus; I have not been able, however, to make out clearly a wall separating these smaller internal cells from the larger ones around them.

The intermediate zone (Plate 6, Fig. 30 t) has in sections the appearance of a nearly empty space. It is in life perhaps occupied by a gelatinous substance with few slender cells. It may, however, be a mere artifact produced by shrinkage.

The outer zone is composed of two layers, an inner layer of cylindrical cells arranged vertically to the surface (Plate 6, Fig. 30 l) and an outer layer of ordinary connective tissue composed of slender cells arranged paratangentially (cd) which forms the superficial covering of the organ in the orifice of the pigment sheath. The protoplasm of the cylinder cells of the inner layer is concentrated at their proximal ends which abut on the intermediate zone. Here also the nucleus is situated. The rest of the cell body is very transparent and the cell walls are difficult to make out. These cells do not take stains readily and thus essentially differ from the polyedric cells of the inner zone. In their microchemical behavior and their general appearance they resemble the cells of the middle region of the radiating organs of Argyropelecus and Sternoptyx.

A blood vessel, artery, (Plate 6, Fig. 30 b) of considerable size entering the organ at the innermost point was observed in several sections.

Myctophum aurolaternatum Garman.

Plate 5, Figs. 21–23.

This species has been described by Garman ('99, p. 254, Plate 55, Fig. 3). His statements concerning the distribution of the radiating organs agree with my observations, but his figure ('99, Plate 55, Fig. 3) differs in several respects from what I find in the specimen examined.

The radiating organs are for the most part nearly equal in size about 600 μ in diameter. They are provided with reflectors, lustrous, and therefore, although so small in size, quite conspicuous.

There are on each side 3 mandibular (Plate **5**, Figs. 21, 22 ma), — these are mentioned by Garman ('99, p. 265), but not represented in his figure ('99, Plate 55, Fig. 3),— 4 branchiostegal, 2 opercular (op),— the lower one, which is smaller than the upper one, is not represented in Garman's figure ('99, Plate 55, Fig. 3),— 3 pectoral (pe) forming an arc just behind the gill slit, 5 ventrothoracic (vt), over the last of these 1 anterior lateral (al), 4 ventromedials (ve), 3 mediolaterals (ml) forming an oblique row, 10 anterior ventroanal (va), 1 posterior lateral (pl), over the last one of the former 6 posterior ventroanal (vp) — according to Garman's figure ('99, Plate 55, Fig. 3) 7, — and 2 ventrocaudal radiating organs (vc) at the base of the tail.

All the organs examined appear to have the same structure. Viewed from the surface each appears as a lustrous spot enclosed above and at the sides by a dark strip, which has the shape of a horseshoe open below. Each radiating organ of the body lies between two scales. The outer one which covers it (Plate **5**, Fig. 23 ss) is convex and possesses near the centre an II-shaped thickening (t) produced by a local accumulation of calcareous laminae, which make the scale very brittle. On treatment with acid the thickening disappears. The horseshoe-shaped pigment stripe mentioned above is attached to the inner side of this scale. An axial section of the organ vertical to the medial plane of the fish passes through the apex of the horseshoe (p). The lower scale (si) is concave; on its inner side a continuous layer of pigment (pp) is observed. The lenticular space between the convex outer and the concave inner scale is for the most part occupied by connective tissue (c). This is composed of a ground substance traversed by slender, elongated cells which are somewhat irregularly curved.

This tissue is rich in blood vessels. The radiating organ proper, that is, the mass of cells (pc) which probably emit the radiation, lies in the middle of this connective tissue. It is pear-shaped, the thinner end extending outward and downward. The cells composing it are flattened and extend parallel to the surface of the body. The protoplasm is quite transparent and each cell contains a large granular nucleus. The blood vessels form a fine-meshed capillary network (b) on the surface of this cell mass, but do not penetrate into its interior.

Radiating organs of this kind seem to be rare in fishes. Somewhat similar ones have been described by Emery ('84, p. 473) from the ventral series of *Scopelus elongatus*.

Chauliodus barbatus Garman.

Plate 8, Figs. 38-40; Plate 9, Figs. 43-46.

This species has been described by Garman ('99, p. 271, Plate K, Figs. 2, 2 a). The radiating organs are very numerous. Three different kinds of them can be distinguished. The differences between these are considerable and clearly discernible with the naked eye. Some of the organs are simple, some composed, as in the fishes described above, of an inner spherical and an outer paraboloidal part. The simple ones again are either uncovered or provided with a pigment sheath. I have designated these three kinds of organs accordingly as simple organs without pigment sheath, simple organs with pigment sheath, and compound organs with pigment sheath.

The simple radiating organs without pigment sheath appear as very small whitish dots. They are arranged in groups of from 4 to 16. These groups are scattered over the medial part of the ventral surface (Plate **8**, Fig. 39 u) and also occur in great numbers on other parts of the surface, chiefly on the back of the fish.

The simple organs with pigment sheath appear as dark spots 300 μ in diameter. They are scattered in great numbers over the whole of the surface and seem to be most numerous on the sides of the head just behind the eyes (Plate **8**, Fig. 38 x). In the barbel there are 8 of these organs (Plate **8**, Figs. 38–40 Ba).

The compound organs with pigment sheath are lustrous, elongated, about 1mm. long and 600 μ broad. Of these organs there are on each side 1 anteorbital (Plate **8**, Fig. 38 ao), 1 suborbital (Fig. 38 so), 18 branchio-

stegal, 8 guttural (Plate **8**, Fig. 39 g), 19 ventrothoracic (Figs. 38, 39 vt), 22 ventromedial (Figs. 38, 39 ve), 11 ventroanal (Figs. 38, 39 a), 17 anterior lateral (Figs. 38, 39 al), and 22 medial lateral (Figs. 38, 39 ml).

The simple radiating organs without pigment sheath are not in a particularly good state of preservation. So far as they could be made out, their structure corresponds with the same organs of *Chauliodus sloani* described by Chiarini ('99, pp. 16, 17). They are spherical or oval, enclosed in a capsule of connective tissue and composed of a layer of superficial, radial, cylindrical elements surrounding a group of central polyedrical cells.

The simple radiating organs with pigment sheath (Plate **9**, Figs. 43, 44) have an oval (Fig. 43) or irregular (Fig. 44) shape. They seem, however, always to be elongated in the direction of their axis. The angle between the axis and the part of the surface of the fish where they are situated is very variable. It may be 90°, the organ then being vertical to the surface (Fig. 43), or it may be smaller, sometimes so small that the axis of the organ is nearly parallel to the surface of the fish (Fig. 44). It appears that this angle is correlated to the shape of the organs, the regularly oval ones being usually vertical to the surface, the irregular ones inclined to it; and it seems that the organs are the more irregular the more obliquely they are situated. These organs are not, as is generally the case, imbedded entirely in the body of the fish, but protrude considerably over the surface, forming rather conspicuous rounded protuberances (Plate **9**, Figs. 43, 44). They are covered distally by a layer of considerable thickness (Plate **9**, Figs. 43, 44 h) which appears structureless and transparent in the sections. Laterally and proximally they are enclosed in a pigment sheath (p). In the regularly oval organs of this kind the axis of which is vertical to the surface (Fig. 43) the pigment sheath extends only over the part of the organ imbedded in the body of the fish. In the irregular ones (Fig. 44) with oblique axis it covers also the proximal portion of the protruding part. The pigment sheath is thickest at the proximal apex of the organ and gradually thins out towards the margin. Its distal orifice is of considerable extent, and occupies about a third of the whole surface. In this a fine connective-tissue membrane (Plate **9**, Figs. 43, 44 c) is extended which here replaces the pigment sheath. In this thin layer which separates the radiating cell mass proper from the structureless outer covering mentioned above, nuclei, appearing paratangentially elongated in axial sections of the organ, are observed. The interior of the organ is occupied by a mass of poly-

edrical cells in the centre, and cylindrical elements on the surface. The latter (Plate 9, Figs. 43, 44 pc) resemble a cylinder epithelium clothing the pigment sheath and distal connective-tissue membrane internally. They are not vertical to this surface however, but so arranged as to converge to a point within the organ very near its proximal apex. In the distal part of the organ these cells are short, hardly longer than broad. Inwardly they increase very rapidly in length and those situated at the sides are nearly half as long as the organ itself. The nucleus is conspicuous, spherical, or radially extended, oval, and always situated at the distal end of the cell. The protoplasm is granular. The limits between these cells are distinct enough distally, but become very indistinct centrally and finally vanish altogether; in the proximal part of the organ to which these cells converge, no trace of cellular division is discernible. This part of the organ is occupied by a granular protoplasmatic mass (Plate 9, Figs. 43, 44 m) in which neither cell walls nor nuclei are met with. The proximal apex itself is in the regular oval organs free from these cells, or cells of any kind, the granular mass (m) extending here right up to the pigment sheath (Plate 9, Fig. 43). In the axial sections of irregular organs, however, a network of cell limits with nuclei in the meshes is usually observed in the part appearing as the proximal apex (Plate 9, Fig. 44). It seems to me, however, that this point does not exactly correspond to the proximal apex of the regular organs and that the "cells" seen there are transverse sections of the same kind of superficial cylinder cells as appear cut longitudinally elsewhere. These organs being so very irregular in shape, an irregularity in the arrangement of the superficial cylinder cells, giving rise to such an appearance of axial sections, would be not at all surprising.

The inner mass of polyedrical cells (Plate 9, Figs. 43, 44 l) has the shape of a bee-hive or truncate cone resting with its broad base on the distal cylinder cells and extending inward a good way beyond the centre of the organ. The distal cells of this mass are smaller and arranged irregularly, the proximal ones larger and situated in more or less clearly pronounced longitudinal rows. In their appearance these cells differ essentially from the cylindrical elements surrounding them. Their nuclei are pretty large, spherical, or flattened radially, and their protoplasm is transparent and free from granules. Picric acid stains them a bright yellow. The superficial cylindrical cells are comparable to the cells forming the inner region of such radiating organs as those described above of Argyropelecus and Ster-

noptyx; the inner polyedrical cells on the other hand resemble the cells of the middle region of the organs of these fishes.

Three of the simple radiating organs with pigment sheath in the barbel are joined to form a composite mass. Two of these are irregular and lie symmetrically right and left opposite each other. The third is a regular one and lies between the other two. The axes of the two former lie in a plane vertical to the axis of the barbel; the axis of the latter is orientated longitudinally, parallel to the axis of the barbel. A close inspection of a continuous series of sections through this organ reveals the remarkable fact that the central one of these three organs is *completely* enclosed by the pigment layer on all sides, a thing I have not observed in any other radiating organ, although Leydig ('79, p. 369) mentions having occasionally seen simple organs with pigment sheath of *C. sloani* thus entirely enclosed by pigment. Supposing, as one surely has a right to do, that the pigment sheath intercepts the radiation, we would have in that organ of the barbel, and in the similar ones observed by Leydig, radiating organs unable to radiate. A careful examination of these organs completely surrounded by pigment in Chauliodus may be warmly recommended to future investigators.

According to Chiarini's description ('00, p. 16, Plate **5**, Fig. 6) the simple radiating organs with pigment sheath of *Chauliodus sloani* are very similar; his figure (6) however differs somewhat from mine (Plate **9**, Figs. 43, 44). Chiarini states that in staining the superficial cylinder cells with haematoxilin-eosin the nucleus absorbs the former, the protoplasm the latter.

The compound radiating organs with pigment sheath (Plate **9**, Figs. 45, 46) on the body are directed downward. Their axis is vertical, and parallel to the median plane of the fish. Thus the angle between it and the adjacent part of the surface is much larger in the ventral rows than in the lateral. In the latter it is very small, often appearing to be nearly *nil*, the axis then being approximately parallel to the adjacent surface. In their external shape these organs resemble the compound organs of *Lychnopoles argenteolus* described above. They are composed of a proximal spherical (Plate **9**, Fig. 45 A) and a distal paraboloidal part (D). These parts are separated by a sharp and well-defined stricture (C) of considerable depth. The proximal part forms about three quarters of a very regular sphere. The distal part is short, broad, and cut off obliquely at the base, where it abuts on the surface. With the exception of the oblique terminal face of the distal paraboloidal part, the whole organ is enclosed in a stout pigment sheath (Plate

9, Figs. 45, 46 p). The cells composing the sheath contain brown pigment. They are very closely packed towards the inner well-defined and perfectly smooth surface. Towards the outer side they are farther apart and this surface is not so well defined, the pigmented tissue passing here somewhat gradually into the unpigmented tissue surrounding the pigment sheath. In the distal paraboloidal part of the organ a lustrous reflecting layer (Plate 9, Fig. 45 r) composed of slender fibres, is found within the pigment sheath. In the proximal spherical part no such reflecting layer could be made out. A connective-tissue membrane (Figs. 45, 46 c) clothes the whole organ. In the proximal spherical part it appears to rest immediately on the pigment sheath, in the distal paraboloidal part it rests on the reflecting layer. Distally this membrane merges into the transparent connective tissue (Fig. 45 d) which occupies the triangular space between the distal limit of the radiating cell mass proper and the outer surface of the fish. From the whole of the connective-tissue capsule fine radial septa extend inward.

The radiating cell mass proper is composed of three regions, an inner (Fig. 45 i), a middle (m) and an outer (o). The inner region occupies the whole of the proximal spherical part of the organ with the exception of a distal conic sector. It is composed of large, elongate pyramidal cells (Figs. 45, 46 pc). These are arranged radially in a very regular manner and nearly vertical to the connective-tissue capsule, on which their bases rest. They do not quite reach the centre to which they converge. This is occupied by a plug-shaped mass of small cells (Plate 9, Figs. 45, 46 a) which appears to be connected with the radial septa extending inward from the connective-tissue capsule enclosing the radiating cell mass. These septa can often be made out between the pyramidal cells. In sections large blood vessels (Plate 9, Fig. 46 b) are frequently seen extending radially inward from the surface to the central cell mass. Here they continue their course between the latter and the proximal ends of the pyramidal cells, and seem to give off exceedingly fine branches which extend radially outward between the pyramidal cells (Plate 9, Fig. 46) along the connective-tissue septa, separating the latter from one another. The pyramidal cells themselves (Plate 9, Figs. 45, 46 pc) are occupied at their distal end by protoplasm staining deeply with haematoxylin (Plate 9, Fig. 46 pt) whilst their central and proximal parts (ph), about five sixths of the whole, show no great affinity for haematoxylin and other stains. The protoplasm occupying this central part of the cell is, however, not hyaline but distinctly granular. In

the distal highly stainable terminal part of each cell one rather small nucleus (nu) is situated.

The middle region (Plate 9, Fig. 45 m) occupies the distal sector of the proximal spherical part of the organ and the proximal portion of the distal paraboloidal part. The proximal limit is conic, the distal limit very regularly convex. The cells occupying the space between these limits (l) are well defined and polyedric in shape. The distal ones are small. From here they increase in size inwardly, the innermost ones being four to five times as large as the outermost ones. The protoplasm of these cells is homogeneous, not granular, and hardly stainable with haematoxylin. It shows a great affinity to picric acid and the whole cell mass of this region appears bright yellow in sections stained with picric acid-haemotoxylin. The nucleus is nearly spherical and larger in the large cells than in the small.

The distal limit of the outer region is nearly a plane vertical to the axis of the organ, and so, its inner limit being concave and some distance away, the outer region (Plate 9, Fig. 45 o) has the shape of a thick plane concave lens. From the mass of connective tissue which abuts distally on the outer region, septa, nearly vertical to the limiting surface and parallel to the axis of the organ, extend inward, dividing the outer region into prismatic facets rounded off distally. These facets are occupied by small elongated cells, the protoplasm of which behaves towards stains in a similar manner as the protoplasm of the cells of the middle region.

The compound radiating organs of Chauliodus were first studied in *C. sloani* by Leuckart ('64, pp. 153–155). According to his description these organs of *C. sloani* are similar to those of *C. barbatus*. Leuckart chiefly studied the branchiostegal radiating organs (l. c., p. 154). These are cylinders, 1 mm. long and 500 μ broad. Their distal portion is occupied by a structure Leuckart considers as a lens. From the proximal face of this a conic protuberance arises, penetrating some distance into the inner cell mass; as mentioned above such a cone is also observed in *C. barbatus*. The reflecting layer consists of hexagonal pavement cells occupied by numerous crystals. In the outer part of the distal mass, that is, in the "lens," Leuckart claims to have seen fibres, whilst the inner part, and the proximal cone are composed of closely packed rods 5 μ thick radiating from the apex of the cone. The substance composing these rods is highly refractive. No fibres or rods of this description occur in the middle and outer regions, which correspond to Leuckart's "lens," in the compound organs of *C. barbatus*. The

proximal mass which Leuckart terms "Glaskörper," and which corresponds to the inner region, is composed of large crystal-clear radial cones similar to cells; Leuckart, however, does not consider them as such, not having been able to find a nucleus in them. Each organ is supplied by a slender nerve. Leuckart considers these organs as accessory eyes, "Nebenaugen." It is noteworthy that in the discussion following the reading of this paper Claus (Leuckart, '64, p. 155) drew attention to the similarity between these organs and the well-known structures of Euphausia, which were at that time also considered as accessory eyes.

Ussow ('79, pp. 94–97, Plate 1, Figs. 1, 2, Plate 4, Figs. 25, 26) has also described the structure of the compound radiating organs of *C. sloani*. He finds them composed of two semispherical parts, the outer one of which is occupied by a gelatinous mass, colorless and transparent in the living fish, but coagulating and becoming opaque on being treated with the reagents used for preserving the specimen. Below this gelatinous mass a mushroom-shaped "lens" (79, Plate 2, Fig. 6 Kl) is seen, the cylindrical stalk of which extends inwards, whilst the semispherical upper part, composed of conic elements, protrudes into the outer gelatinous mass. This "lens" appears to correspond to our middle region. The conic elements of its distal, semispherical part are according to Ussow attenuated proximally to fine threads, which extend inward parallel to the axis of the organ and form the stalk of the mushroom, in which they are connected with granular multipolar cells. Concerning the inner region Ussow merely corroborates the previous statements of Leuckart. These, however, he does not seem correctly to have understood. Ussow also states that a slender nerve leads to each organ. His description and also his figures are very different from what subsequent authors have seen in these organs of *C. sloani* and show very little similarity to the structure of these organs in *C. barbatus* described above.

Leydig ('79, pp. 365–382, Plate 15) examined the radiating organs of *C. sloani* simultaneously with and independently of Ussow. His material, a specimen preserved in spirits for several years, was not good, but nevertheless his results were more valuable than those of Leuckart and Ussow. He also chiefly studied the compound organs; his notes on the others have been referred to above. The compound organs are surrounded by annular blood vessels and a slender nerve branch leads to each. The distal portion of the compound organ is composed of two parts, an outer cap and a lower mass.

The proximal cone described by Leuckart is part of this latter. In the distal cap club-shaped cells are met with, the distal end of which is the thicker one. It is laterally enclosed by stout cell walls, but destitute of a terminal membrane. The thin proximal end passes into a fine thread of considerable length. The nucleus is situated in the lower end of the thick part of the cell. The cells of the lower mass of the distal portion are of greater size, more finely granular, and have a larger nucleus. The proximal cone appears to be composed of processes of these cells which converge towards its apex. This cell mass is traversed by fibrous strands, extending inward from the surface and forming a kind of scaffolding which has the shape of a honey comb. The cells of this honey comb evidently correspond to the connective-tissue facets described above of *C. barbatus*. The cones occupying the proximal part (inner region) of the organ are cells. Leydig found a nucleus in their granular outer end. The centre to which these conic cells converge is occupied by a finely granular substance ("Punktsubstanz"). Leydig thinks that the nerve leading to the organ terminates in this "Punktsubstanz" and that the cells both above (cone of the middle region) and below (inner region) are connected with it. A portion of the reflector forming half a ring outside the stricture has a distinctly golden lustre. Leydig calls these organs accessory eyes, but uses this term ("Nebenaugen") with a certain amount of mistrust. From this and from a quotation of Willemoes-Suhm, which he publishes, one can conclude that he was already at that time, although calling these organs eyes, quite open to the view that they had in fact a radiating function.

The descriptions given by these authors are based on material insufficiently preserved and studied without the application of modern methods. They can therefore claim hardly more than an historical interest. Now, however, we have to review the papers by Brandt (1899) and Chiarini (1900) in which the compound radiating organs of *Chauliodus sloani* are described in a far more exact manner.

According to Brandt's description ('99, pp. 447–450) these organs of *C. sloani* seem to be identical in structure with those of *C. barbatus*. He considers the cells of the inner region as gland cells in which a secretion is formed and then oxidized whereby light is produced, whilst the middle and outer region have no other function than that of conveying the radiation produced to the outer world.

Chiarini ('00, pp. 14–17, Figs. 6–7) also describes the radiating organs of

C. sloani in detail. To his statements concerning the simple organs we have referred above. The compound organs of this fish ('01, pp. 14, 15, Fig. 7) consist, according to him, as in *C. barbatus*, of a proximal, nearly exactly spherical part, to which a funnel-shaped neck, separated by a distinct incision, is attached. In the compound organs of the body the funnel is cut off obliquely where it abuts on the surface of the body. In the branchiostegal organs transversely. Each compound organ consists of an outer pigment layer, a reflector, a connective-tissue capsule, and a central cell mass, in which three regions, an outer, middle, and inner can be distinguished. These regions correspond to the three regions in the organs of *C. barbatus*. Beyond the outer region gelatinous tissue is met with, occupying the space between its outer face and the surface of the fish. The outer region is divided by connective-tissue membranes into very narrow facets diverging distally. The middle region is clearly divided into an outer portion, occupied by polyedrical cells, and an inner portion divided into radial facets. The inner region consists of radially arranged conic cells, the larger central parts of which are fine grained and stainable with eosin but not with haematoxylin, whilst the much smaller peripheral portions forming about a quarter of the length of each cell are readily stainable with haematoxylin. Each of these cells contains one or two nuclei situated in the peripheral portion.

It will be seen from this that the structure of these organs in *C. sloani* is very similar to that in *C. barbatus*. The chief differences between them are the following: in *C. sloani* the facets of the outer region are narrow, the middle region is distinctly divided into an outer and an inner portion, and the cone cells of the inner region contain one or two nuclei; in *C. barbatus*, on the other hand, the facets of the outer region are broad, the middle region is not divided into two clearly distinct parts, and the cone cells of the inner region always contain a single nucleus.

Idiacanthus antrostomus Gilbert.

Plate 8, Figs. 41, 42.

This species was first described by Gilbert ('90, p. 54), later more in detail by Garman ('99, p. 280). It possesses two kinds of radiating organs, one without, the other with, a pigment sheath. The former are exceedingly small and arranged in two large elongate groups (Plate **8**, Fig. 41 u) on the

sides of the head under the large suborbital organ with pigment sheath, and in six longitudinal rows, three on each side, of smaller groups on the body. The intervals between these small groups on the body are equal in extent to the intervals between the larger organs with pigment sheath, and the former alternate with the latter.

The radiating organs with pigment sheath have a silvery lustre. Those of the body measure about 300 μ in diameter; the suborbitals are larger. There are on each side 1 suborbital (Plate **8**, Fig. 41 so), 13 branchiostegal, 10 guttural (Fig. 42 g), 25 ventrothoracic (Figs. 41, 42 vt), 20 ventromedial (Figs. 41, 42 ve), 35 ventroanal (Figs. 41, 42 a), 25 anterior lateral (Fig. 41 al), 20 medial lateral (Fig. 41 ml), and 35 posterior lateral (Fig. 41 pl), radiating organs with pigment sheath.

The small organs without pigment sheath are spherical, enclosed in a connective-tissue capsule, and composed of radially arranged cells, which usually enclose a central cavity.

The organs with pigment sheath closely resemble the compound organs of *Chauliodus barbatus* described above. The suborbital organs are so disposed as to throw their radiation into the field of vision; the organs of the body are directed downward.

Stomias hexagonatus Garman.

Plate 10, Figs. 47–51.

This species has been described by Garman ('99, pp. 276, 277, Plate 56, Fig. 5). It possesses five different kinds of radiating organs. An organ in the barbel, a pair of suborbital organs, and on the body simple organs without pigment sheath, simple organs with pigment sheath, and compound organs with pigment sheath.

The radiating organ in the barbel (Plate **10**, Figs. 47, 48, 50), lies in a thickening 1.5 mm. long at the end of the barbel (Fig. 47, 48 L). From its distal part three short terminal threads arise. The radiating organ itself (Plate **10**, Fig. 50), is oval and placed transversely in the swelling of the barbel, the long axes of the two crossing nearly at right angles. It is enclosed in a stout connective-tissue sheath (Plate **10**, Fig. 50 c), and composed of two parts, an upper, dorsal, smaller, dorsoventrally compressed (A), and a lower, ventral, spherical part (B). The smaller upper part is enclosed in a somewhat loose pigment sheath (p), lying within the upper part of the

connective-tissue sheath enclosing the whole organ. The upper portion of this pigment sheath forming the roof of the upper part is dome-shaped, the lower portion, forming its floor and separating it from the lower spherical part, is flat or even a little concave. At the circular line where the upper part joins the lower a conspicuous ring-shaped thickening of the pigment layer (pt) is observed. From this a small annular ridge extends outwards and downwards, forming the rudiment of a cup enclosing the basal, upper portion of the lower, spherical part of the organ.

The interior of the upper part of the organ is traversed by a horizontal, strongly pigmented membrane (pm), which divides it into a larger upper and a smaller lower chamber. In both these chambers large cavities (cv) are seen. In the upper one there seems to be only one such cavity. This is situated ventrally and surrounded by a special endothelial cell layer, separating it from the transparent connective tissue occupying the dorsal and lateral parts of the upper chamber. In the lower chamber more cavities than one are seen. These lie dorsally. Below them in the ventral part of this chamber large sinuous blood vessels (b) extend.

The lower part of the organ (B) is covered dorsally by the pigmented floor of the upper part of the organ and the annular rudiment of a pigment cup referred to above. Laterally and ventrally it is surrounded by the transparent connective-tissue sheath only. From the middle of the roof of this lower spherical part of the organ a cylindrical thread composed of connective tissue (z) arises which extends vertically downward to its centre. This thread is composed of longitudinally arranged, spindle-shaped connective-tissue cells with oval nuclei. Along this thread blood vessels (b) and probably also a nerve extend from above down to the centre of the sphere. The lower end of the thread is thickened to form a terminal knob in which a sinuous cavity, filled with blood corpuscles, is observed. Apart from this thread with its terminal knob the whole of the sphere is occupied by large radially arranged conic cells (pc) equal in length to its radius. In arrangement and structure these cells are similar to the conic elements in the inner region of the compound organs of *Chauliodus barbatus* described above. They are, however, more slender. The inner seven eighths are occupied by finely granular, transparent protoplasm not readily stainable; in the outer eighth of the length coarser grained protoplasm showing great affinity to hæmatoxylin and other stains is observed. In the peripheral part of each cell one small, spherical nucleus is situated.

The suborbital radiating organs (Plate **10**, Fig. 47 so) are represented by Garman in his figure ('99, Plate 56, Fig. 3), but not mentioned in his description ('99, pp. 276, 277). The suborbital organ lies below and behind the eye; it appears nearly spherical, is 800 μ in diameter, and enclosed in a pigment sheath and a connective-tissue capsule. The pigment sheath forms a sac, the opening of which abuts on the surface of the fish. It is composed of concentric layers of rather loosely scattered cells containing brown pigment. Within this pigment sheath lies the connective-tissue capsule. The structure of the inner cell mass could not clearly be made out, as these organs were somewhat injured in the specimens at my disposal.

The simple radiating organs without pigment sheath appear as small white dots 100 μ in diameter. They are scattered in great numbers over the ventral side of the fish and also occur in the three terminal threads of the barbel mentioned above. They are more or less spherical, enclosed in connective-tissue capsules and composed of pretty large radially arranged cells with conspicuous nuclei.

The simple radiating organs with pigment sheath are met with on the hexagonal scales of the body and also on the head of the fish. They appear as dark spots and measure 300 μ in diameter. On each ventral scale a group of 7 of these organs occurs, upwards they gradually become scarcer, and near the dorsal medial line of the fish only one such organ is found on each scale. In their structure these organs resemble the simple radiating organs with pigment sheath of *Chauliodus barbatus* described above. The hyaline mass which in the latter covers the organ outside, is, however, absent in these organs of *Stomias hexagonatus*.

The compound radiating organs with pigment sheath (Plate **10**, Figs. 47, 48, 49, 51) appear as conspicuous dots with a silvery lustre and are 300–500 μ in diameter. On the whole they are largest in front and decrease in size backwards. There are on each side of the body 12 guttural (Plate **10**, Figs. 47, 48 g), 16 branchiostegal, 38 ventrothoracic (Figs. 47, 48 vt), above these in a parallel row 37 anterior lateral (Figs. 47, 48 al), 10 ventromedial (Figs. 47, 48 ve), 10 medial lateral (Figs. 47, 48 ml), and 19 ventroanal (Figs. 47, 48 a) compound radiating organs with pigment sheath.

Two different kinds of these organs can be distinguished. The first somewhat larger kind is represented by the anterior compound organs of the body which form the ventrothoracic and anterior lateral rows. All the other compound organs belong to the second, smaller kind.

The compound organs of the first kind (Plate **10**, Figs. 49, 51) are spherical and have a short process directed downwards towards the outer surface. They might be compared to spherical bottles with small necks placed upside down. The axis of the organ is vertical, parallel to the median plane of the fish. The ventral organs, that is, those belonging to the ventro-thoracic row, therefore abut nearly vertically on the surface, whilst the lateral ones, that is, those belonging to the anterior lateral row, are very oblique and enclose but small angles with the surface of the fish. In the former the "neck" appears cut off transversely; in the latter, obliquely.

The pigment sheath (Plate **10**, Fig. 51 p) enclosing the organ is rather thin and composed of cells containing brown pigment. It surrounds all parts of the organ with the exception of the terminal face of the "neck."

As in other compound radiating organs we also find in these below the pigment layer a reflecting layer. This is however not at all extensive, being confined to the distal part of the neck-shaped portion, where it forms a ring (Plate **10**, Fig. 51 r) surrounding the "neck." This reflecting layer is composed of highly refractive threads.

Within the pigment sheath and, where this is developed, the reflecting layer, a connective-tissue membrane is met with which entirely surrounds the inner cell mass and forms a perfectly closed capsule, from which diverticula extend inwards.

The greater part of the interior of the proximal, spherical part of the organ is occupied by large radially arranged conic cells which converge towards the centre of the sphere. These cells are very similar to the conic elements in the inner region of the compound organs of *Chauliodus barbatus* and like them consist of a long, proximal, finely granular part (ph) not readily stainable, and a short, distal part (pt) showing great affinity to haematoxylin. The nucleus is remarkably small and situated in the distal staining part of the cell. These cells are divided from each other by fine connective-tissue membranes extending from the outer connective-tissue capsule radially inward towards the centre. In these membranes small radial blood vessels (b) can be made out.

The "neck" of the organ (Plate **10**, Fig. 51 cy) above referred to is a stout cylinder, circular in transverse section, the axis of which coincides with the axis of the whole organ. This cylinder is surrounded by an extensive annular cavity (s) dividing it from the connective-tissue capsule forming the innermost layer of the outer covering of the organ. The outer, distal, ter-

minal face of the cylinder is rounded off, simple, convex; the inner, proximal face is drawn out to form a regular cone about as high as broad, which penetrates the mass of radial conic cells occupying the proximal spherical part of the organ. The apex of this cone lies a little way above the centre of this sphere. The whole appears as a cylindroconic plug (Plate **10**, Fig. 51). From that part of the connective-tissue capsule of the organ which covers the terminal face of this plug, diverticula extend inwards parallel to the axis. These form parallel facets. The central (axial) facet (cc) is the longest; it extends to the apex of the cone, whilst towards the sides of the cylinder the facets become shorter. Transverse (Plate **10**, Fig. 49) and longitudinal axial (Plate **10**, Fig. 51) sections of the plug-shaped outer part of the organ show that the contents of the central facet (Plate **10**, Figs. 49, 51 cc) are different from those of the other facets (pc). In staining with Van Gieson's haematoxylin-picric acid-fuchsin one finds that the latter take up haematoxylin and acid-fuchsin very readily, whilst the substance in the central facet absorbs only the picric acid. It also stains with eosin. In the distal parts of the outer facets nuclei and cell limits can be distinctly seen; here pretty large elongate cells are situated. In transverse sections of the distal part of the plug one sees two or three cell sections lying side by side in each facet (Plate **10**, Fig. 49). In the proximal parts of the outer facets and throughout the whole length of the central facet cell limits cannot be made out and nuclei are hardly to be seen.

Ussow ('79, p. 91) has described these organs in *Stomias barbatus*. He says that they are similar to those of Chauliodus, but that the middle region, which he represents as a mushroom-shaped body (see above) in *Chauliodus sloani*, is absent in *Stomias barbatus*.

Organs similar to these have been described by Chiarini ('00, p. 12, Fig. 3) from *Maurolicus poweriae*. He says that each of the cells of the inner spherical part and also of the cylindroconic plug, that is, the "neck" of the organ, often contain *two* nuclei. These cells are always mononuclear in *Stomias hexagonatus*. In longitudinal sections the limits between the cells are often so indistinct that one can indeed be easily misled on this point and imagine that the two or three nuclei seen imbedded in an apparently continous protoplasmatic mass belong to one and the same cell. Transverse sections, however, show, at least in the distal part, the cell limits well enough and make it clear that here each nucleus belongs to a separate cell.

The compound radiating organs of the second kind which are met with

on the hinder part of the body have the same structure as the compound organs of *Chauliodus barbatus* described above. It is therefore not necessary to give a detailed account of them.

(2) THE FISHES WITH RADIATING DISCS.

Bassozetus nasus Garman.

Plate 4, Figs. 14-17.

This species has been described by Garman ('99, pp. 159, 361, Plates 77, 78). Its head shows a number of deep depressions (Plate **4**, Fig. 14). On removing the semitransparent skin from it a number of subdermal, clearly defined, white, somewhat elongated, rhombical patches 1–3 mm. long are exposed to view. A stout nerve fibre leads to each one of these. There are on each side of the head 3 maxillary, 6 orbital, 3 ethmoidal, 3 frontal, 5 occipito-parietal, 5 mandibular, and 4 opercular patches of this kind. These I designate as radiating discs.

Each radiating disc appears as a thickening of the membrane which lies close to the bone and can be easily withdrawn therefrom. The basal part of the thickening, that is, the part lying next the bone, contains pigment cells, which form a pretty continuous basal layer (Plate **4**, Figs. 15–17 p). Numerous blood vessels (Plate **4**, Fig. 17 b), enter the thickening from all sides and form a dense capillary reticulation in its central part, just below the upper surface. The stout nerve (Figs. 15–17 n), mentioned above, which I designate as the main disc nerve, also enters the thickening at its margin. Without appreciably diminishing in width it extends through the basal part of the thickening to its centre where it abruptly divides into a number of fine branches. These lie in a paratangential plane and radiate in all directions in it. Repeatedly ramifying they approach the margin of the thickening where they become obscured by the pigment cells which form a dense reticulation (Figs. 15, 16 p), lying at a rather lower level than the nerves. No peculiar histological differentiation could be made out within the disc. In transverse sections (Fig. 17) one merely sees faint paratangential lines and elongated nuclei also disposed paratangentially. Thus it appears to be composed of paratangentially extended plate-like or fibrous cells overlying each other in several layers. Between these cells the nerve branches extend. Judging from the appearance of the whole organ

one should say that the radiation — supposing that a radiation is really emitted from it — is produced by the nerve branches themselves and that the paratagential cells are merely packing.

These organs of Bassozetus resemble the basal part of the radiating discs of Halosaurus to be described below and so one might suppose that the superficial layer of cylindrical cells there present also occurs here but has been lost *post mortem.* It must however be remarked that no trace of a previous presence of such a cell layer could be made out in transverse sections of the radiating discs of *Bassozetus nasus.*

Leucicorus lusciosus Garman.

Plate 3, Figs. 10-13.

This species has been described by Garman ('99, pp. 148, 361, Plates 38, 74, Fig. 1). After removing the semitransparent skin of the head the radiating discs underlying it are exposed to view. They appear as roundish white spots 1.5–3 mm. in diameter overlying the bones of the skull. They are remarkably hygroscopic. If one places one of the discs preserved in alcohol in water it rapidly increases in size and swells to the bulk of a pea. On each side of the head there are 3 maxillary, 4 orbital, 2 ethmoidal, 3 frontal, 7 occipitoparietal, 4 mandibular, and 5 opercular radiating discs.

These organs are similar to, but in their finer structure more highly differentiated than, those of *Bassozetus nasus* described above. A very stout nerve (Plate **3**, Figs. 11, 12 n) enters the disc from the side and extends, as in Bassozetus, to its centre without decreasing in thickness. Besides this main disc nerve there are other smaller nerves (Figs. 11–13 n′), which enter the disc in a similar manner. In some cases it appeared as if the latter connected different discs with each other. Numerous large blood vessels (Figs. 11–13 b) are met with. These chiefly extend from two opposite sides towards the centre of the organ and here, bending abruptly at nearly right angles, and ramifying, form a vascular ring of rhomboidal shape. From this ring numerous branches are given off towards the interior which supply the central part of the disc. These blood vessels form a dense superficial reticulation (Fig. 13).

The large main disc nerve extends through the basal part of the disc and terminates in the centre of the rhomboidal space surrounded by the blood-vessel ring. Here it abruptly divides into numerous branches all diverging

radially in a paratangential plane. In the central part of the lower portion of the disc numerous large cavities, which appear empty in sections (Fig. 13 cv), are observed. At the base of the disc a layer of scattered pigment cells (Fig. 13 p) occurs. No particular structures could be made out in the tissue forming the disc itself. In transverse sections (Fig. 13) through it one sees paratangentially orientated plate-like or spindle-shaped elements, probably connective-tissue cells, sections of nerves and blood vessels and here and there granular elements which look like nerve cells.

As in the case of Bassozetus (p. 198), also here in *Leucicorus lusciosus* the possibility of the discs examined being incomplete must be taken into consideration. If the discs as observed were covered by a layer of cylindrical cells these organs of Leucicorus would become very similar to those of Halosaurus described below. Such a cylinder cell layer may have been present on these organs during life; I failed however to find any trace of it in the sections.

Halosaurus radiatus Garman.

Plate 11, Figs. 52–57.

This species has been described by Garman ('99, pp. 298, 364, Plate 60, Figs. 2, 2 a, Plate 84, Figs. 3–6). The radiating discs are situated on the head and, according to Garman ('99, p. 298, Plate 60, Fig. 2, Plate 34, Figs. 3–6), also in a longitudinal row on each side of the body. They lie under the skin and are spindle-shaped, the long axis being disposed paratangentially. The largest are 3 mm. long. On each side of the head there are 7 maxillary, 7 orbital, 8 ethmoidal, 4 occipitoparietal, 4 mandibular, and 9 opercular radiating discs. Those on the body could not be made out in the somewhat injured specimen at my disposal.

In *Halosaurus radiatus* the radiating discs are obviously connected with the slime-canal system. They are in fact local differentiations of the walls of certain slime canals. The cephalic slime canals in which the organs of the head lie, extend as usual paratangentially below the outer skin. These slime canals are enclosed in a stout, apparently structureless sheath (Plate 11, Fig. 56 s). Within this a layer of connective tissue (Figs. 56, 57 c) is met with, in which slender, probably spindle-shaped cells arranged paratangentially can clearly be made out. This connective-tissue layer is stouter on the lower side, that is, in the floor, than on the upper side, that is, in the roof of

the canal (Fig. 56 cv). The outer structureless sheath of the canal is separated from the periost of the bone on which it rests by a thin layer of scattered pigment cells (Fig. 56 p). The radiating disc is situated in the floor of the canal. Seen from the surface (Plate **11**, Figs. 53–55) it has the shape of a rhomboidal spindle with obtuse points. The most important part of it is a single layer of slender somewhat irregularly cylindrical cells (Plate **11**, Figs. 56, 57 d) which form an epithelial layer. A stout main disc nerve (Plate **11**, Figs. 53–56 n) and one or two smaller accessory nerves (Figs. 53–55 n′) lead to this cylinder cell layer. The main nerve rises obliquely towards the centre of the cylinder cell layer, arrived at the base of which it suddenly divides into numerous radiating branches extending paratangentially below the cylinder cell plate. Here also an exceedingly dense capillary network (Figs. 56, 57 b) is met with forming a conspicuous blood-vessel layer between and under the basal parts of the cylinder cells. The large vessels leading to this network (Figs. 53–56 b′) are very conspicuous, particularly in surface views (Figs. 53–55).

The cylinder cell plate (Figs. 56, 57 d) is perhaps not wholly composed of cylinder cells equal in length to the thickness of the plate. There is a marginal zone (Fig. 56 m), where in transverse sections through the plate the cells appear to be polyedrical and to form several layers. It is probable, however, that also here the cells are in reality cylindrical and form a single layer and that the appearance seen is only the consequence of the marginal cells not extending, as the others do, in the plane of the section. They would therefore not, as the cells of other parts of the plate, be cut longitudinally, but more or less transversely, and thus assume the appearance of polyedrical elements lying in several layers. Also in the centre of the plate there seems to occur a slight irregularity.

The greater part of the elongated rhomboidical plate formed by this cell layer is flat. Its margins, in which the apparent multiplication of cell layers mentioned occurs, are markedly raised. In the middle, along the short diagonal of the elongate plate, a transverse groove extends. All the cylinder cells with the exception of the marginal ones, arise vertically from the floor of the plate. Most of them show a distinct curvature increasing towards the upper end (Fig. 57). In the central groove the cylinder cells lie close together, in the other parts of the plate they are apparently separated by intercellular spaces of considerable width (Fig. 57). Possibly this appearance is merely the expression of the presence of thick lateral cell

walls similar to those observed by Leydig and others in certain cells of the ocellar radiating organs described above. If on the other hand intercellular spaces are really present — and the appearance is in favor of this assumption — the question arises whether they are present in these cell plates in life or merely artifacts produced *post mortem* by transverse cell shrinkage. In the lower end of each of these cells a large oval granular nucleus is observed. These nuclei form a single layer in the basal part of the plate. In the marginal zone nuclei are also observed higher up, and the same is the case in the central groove, where a few nuclei are likewise seen at a higher level. It is doubtful, however, whether these latter belong to the cylinder cells. It seems rather that they are the nuclei of slender spindle cells here interposed between the cylinder cells. The protoplasm of the cylinder cells is pretty granular and stainable with acid-fuchsin and haematoxylin. These stains are taken up more by the terminal than by the central parts of the cells. The cells of the central groove show a marked affinity for picric acid; other stains are hardly at all absorbed by them.

Transverse sections (Plate **11**, Figs. 56, 57) show that the intercellular spaces between the cylinder cells above mentioned do not extend quite to the upper surface of the cell plate. Here the upper ends of the cells, in most cases considerably curved, are in direct contact with each other and form a superficial pellicle apparently quite continuous and in sections somewhat resembling a cuticle.

I have previously described ('87, pp. 309–313, Plate 73, Figs. 45–48, 54–64) the structure of the radiating discs in another species of Halosaurus, *H. macrochir*. In this species a pair of large glandular radiating organs also occurs under the gill covers. These have a different structure. The smaller spindle-shaped discs on the sides of the body, however, resemble the radiating discs on the head of *H. radiatus* pretty closely. These are in *H. macrochir* attached to the outer side of the scales over the great lateral slime canal. Below the centre of each disc the scale is perforated by an oblique tube through which a nerve and blood vessels ascend to the base of the disc. In the disc itself a lower layer, chiefly occupied by an exceedingly close reticulation of capillary blood vessels, and an upper composed of slender cells arising vertically, standing side by side, and forming a high epithelium can be distinguished. The individual elements of the latter are spindle-shaped or irregularly cylindrical. In transverse sections through the disc these cells appear separated by clear intervals wider than in the cylinder

cell plates of the cephalic discs of *H. radiatus*. In *H. macrochir* the upper ends of these cells are strongly curved and pass into a superficial pellicle which looks as if it were composed of the upper ends of the cells themselves, drawn out in a thread-like fashion and laid down tangentially.

Macrurus canus Garman.

Plate 5, Figs. 18–20.

This species has been described by Garman ('99, pp. 217, 364, Plates 49, 84, Figs. 1, 2). The radiating discs are situated in the floors of the cephalic slime canals. In surface views they appear elongate hexagonal (Plate **5**, Figs. 19, 20). They are 2–4 mm. long, white in color and very conspicuous. The wall of the slime canal is lustrous and the part surrounding the discs occupied by large and richly ramified dark brown pigment cells (Figs. 19, 20 p) so that they stand out as brilliantly white patches from a dark surrounding. On each side of the head there are 3 maxillary, 6 orbital, 2 ethmoidal, 16 occipitoparietal, 7 mandibular, and 6 opercular radiating discs. A stout nerve, the main disc nerve, (Plate **5**, Figs. 19, 20 n) approaches each of these organs from the side and extends through its basal part towards its centre, where it abruptly divides into numerous paratangentially extending branches. These discs are exceedingly tender structures, and unfortunately not sufficiently well preserved to allow of their minute structure being clearly made out. A square patch occupying the central part of the hexagonal disc is much less transparent than the remainder (Figs. 19, 20), and it seems that the ramifications of the main disc nerve are confined to this. The discs here are certainly not so simple in structure as in Leucicorus and Bassozetus and seem to approach those of Halosaurus. They probably have a structure similar to that of Halosaurus.

Ipnops agassizii Garman.

Plate 1, Figs. 3–5.

This species was described by Garman ('99, p. 259, Plate H, Figs. 2, 2 a). On the upper side of its dorso-ventrally compressed head a whitish patch 12 mm. long and equally broad, composed of two symmetrical halves, a right and a left one, is met with (Plate **1**, Figs. 3–5 d). Moseley ('87, pp. 269–276, Plates 67, 68) has found similar discs in another species of this genus,

I. murrayi, and has examined and carefully described their minute structure. In the material of *I. agassizii* at my disposal these discs are not sufficiently well preserved to allow of their minute structure being studied. All I can say is that I have seen nothing in them that would justify one in supposing that they differed in any way from the organs described by Moseley in *I. murrayi*. The hexagonal cylinder cells of the discs of *I. agassizii* are about 20 μ long and 5 μ thick.

(3) THE FISHES WITH TUBULAR RADIATING ORGANS.

Malthopsis spinulosa Garman.

Plate 1, Figs. 1, 2, Plate 2, Figs. 6-9.

This species has been described by Garman ('99, p. 106, Plates 21, 24). It is (Plate **1**, Figs. 1, 2) a flat fish of horseshoe-shape with a stout conic tail. The organ here to be described which may have a radiating function is a medial tentacular papilla on the forehead just above the mouth (Plate **2**, Fig. 6 te). Garman ('99, p. 106) states that this papilla is contractile and can be extended and retracted at the will of the fish. In the state observed by me it is about 6 mm. long and 1.5 mm. thick. This papilla is situated in a depression so that it protrudes when retracted only slightly beyond the general surface of the fish. The apex of the papilla is divided into three lobes, an upper somewhat leaf-shaped one and a pair of lower massive ones.

The trilobed terminal part of the tentacular papilla of the only specimen of *Malthopsis spinulosa* at my disposal was cut into a series of transverse sections. These (Plate **2**, Figs. 7, 9) show that its trilobed distal part is supported by four stout longitudinal rods of semicartilaginous tissue (Figs. 8, 9 s). The two lower ones are separate, the two upper ones joined to form a band-shaped structure. These rods are enclosed in sheaths of connective tissue from which septa (Figs. 7, 8, 9 c) radiate, chiefly into the massive ventral lobes, the interior of which is divided by them into a number of longitudinal compartments. In the middle of the ventral surface connecting the two ventral lobes a conspicuous longitudinal ridge is observed, the interior of which is occupied by a pair of longitudinal muscles, lying close together (Figs. 8, 9 m). These are, no doubt, the muscles which retract the tentacular papilla, while its extension is probably brought about

by the elasticity of the semicartilaginous rods described above or the accumulation of blood in the large longitudinal, sinus-like bloodspace (Figs. 8, 9 b′) which occupies the centre of the tentacular papilla. Other smaller blood vessels (Figs. 8, 9 b) are met with in its superficial parts.

The longitudinal chambers formed by the connective-tissue septa mentioned above, are large and dorsoventrally depressed in the dorsal leaf-like part, whilst they are radially arranged like a fan in the two lower lobes. The connective-tissue walls of these chambers are clothed by a high epithelium composed of a single layer of cylindrical cells. In the sections this cell layer (Figs. 7, 8, 9 pc) is, however, by no means in direct contact with the connective-tissue walls, but separated from them by an apparently empty space of considerable extent (Figs. 7, 8, 9). Thus these cylinder cells form tubes lying within the likewise tubular chambers formed by the connective-tissue septa. The lumina of these tubes (Figs. 7, 8, 9 cv) are narrow and either empty or occupied by a structureless mass, apparently a secretion. The cylinder cells themselves contain a pretty transparent protoplasm, which is strongly stained with picric acid, but hardly at all with haematoxylin. The large, oval, granular nucleus lies in the outer (lower) termination of the cell. Pigment is found chiefly in the outer skin of the dorsal leaf-shaped lobe.

In structure these organs resemble the inner portions of the suborbital organs of *Pachystomias microdon* (Lendenfeld '87, p. 320–322, Plate 71, Figs. 30, 31), where however the cells forming the tubes are not so high. It is particularly to be remarked that also in this part of the suborbitals of *P. microdon* one finds in the sections the tubes formed of these cells separated from the connective tissue surrounding them, by apparently empty spaces.

Chun ('03, pp. 568, 569) has mentioned the occurrence of a frontal tentacular papilla in other species of Malthopsis. He thinks that the organ may emit light, but is doubtful on this point.

On the margin of the body of this fish bud-like protruding organs of peculiar structure (Plate **1**, Figs. 1, 2, Plate **2**, Fig. 6 o) occur, which I will not describe here, being of the opinion that their function is not to radiate. They are ramified, rich in blood vessels, and may be accessory gills, or sense organs. These structures are dealt with in the Appendix.

3. CONCLUSIONS.

The results of the examination of the minute structure of the organs of the fishes collected by the "Albatross" which one can, with more or less certainty, consider as radiating, as described above, illustrate again their great diversity. Not only do the ocellar, disc-shaped, and tubular organs fundamentally differ, but even within these three main groups very great variations are met with.

The best known of those organs are the ocellar. A highly developed organ of this kind, such as the compound organ of Chauliodus is — apart from the connective-tissue support, the nerves and blood vessels — composed of a pigment sheath, a reflecting layer, an inner region of large, highly specialized conic cells, and a middle and an outer mass of specialized polyedrical cells of another kind. Apart from the blood vessels, nerves, and connective tissue, which, as occurring in all organs, of course do not concern us here, *none* of these structures are found in *all* of the ocellar organs described above as radiating. The pigment sheath is absent in the smallest organs of Chauliodus itself. In these, and in others with a pigment sheath, the reflecting layer is absent. The large conic cells of the inner region are absent in the simple organs and in the highly differentiated compound organs of Argyropelecus. The polyedrical cells of the middle and outer region of the compound organs of Chauliodus which usually occur in simple organs are replaced by long spindle-shaped cells in all the compound organs of Lychnopoles and in the anterior compound organs of Stomias.

An analogous diversity is met with in the radiating discs. Whilst in Halosaurus and Ipnops highly specialized cylindrical or spindle-shaped elements, obviously forming a very essential part of the organ, are met with, such cells seem to be entirely absent in the discs of Bassozetus and Leucicorus.

In the tubular organs the diversity is not so great, although here also we find the cells forming the walls of the glandular tubes sometimes high, as in Malthopsis, and sometimes low, as in Pachystomias.

Even the rule, in general holding good, that the outer covering of these organs is transparent and suited to allow the radiation to pass, is not univer-

sally applicable, for we have found at least in one instance in Chauliodus — and Leydig has found the same in other instances — organs, otherwise identical with simple ocellar radiating ones, entirely enclosed in a pigment sheath and therefore unable to radiate at all.

The diversity is in fact so great that we are forced to assume that either not all the organs described as radiating really emit ethereal waves, or if they do, that the waves emitted by different organs are either differently produced, or different in character, or both. Although direct observations of the radiation of these organs are but few, we know (*1*) that some of them at least do emit light, and (*2*) that the light emitted by different organs is often different in color.

It is remarkable that such observations have not been made more frequently, and that Chun who took every deep sea fish caught immediately to the photographic dark chamber, so often failed to observe any light emitted from these organs.

On the whole I should consider it most probable — although very far from scientifically certain — that: (*1*) The organs produce a radiation. (*2*) In the simple ocellar organs and the radiating discs this radiation is an ethereal wave movement directly emitted into the surrounding water. (*3*) In the compound ocellar organs this radiation is either also such a movement or an emission of corpuscles (electron bombardment) and originates in the inner part. It is here not emitted directly into the surrounding water, but acts on the outer part and induces this to phosphoresce and emit ethereal waves. (*4*) The length of the ethereal waves thus directly or indirectly produced by one and the same organ is always the same; that of the ethereal waves produced by different organs is often different. (*5*) In some cases the wave length lies within the visible part of the spectrum; in other cases it may be smaller or greater, and then the radiation is invisible. (*6*) The ethereal waves of the invisible radiations are probably of greater length than those producing the red end of the spectrum because such probably penetrate the water to greater distances and because the remarkable telescopic eyes of some deep sea animals seem to be peculiarly adapted to their perception. (*7*) These long ethereal waves may (if not too long) be of the nature of (ultra red) light, or (if longer) of the nature of electricity.

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APPENDIX.

THE STRUCTURE OF THE BUD-LIKE ORGANS OF MALTHOPSIS SPINULOSA GARMAN.

By EMANUEL TROJAN.

Among the Albatross fishes sent to Professor von Lendenfeld for examination was a specimen of Malthopsis spinulosa Garman. This fish is provided with peculiar bud-like sense organs, which, on account of their function apparently not being a radiating one, were not described in Professor von Lendenfeld's report. Professor von Lendenfeld entrusted me with the examination of the minute structure of these organs. The results are given below.

Garman (1899, pp. 106, 107, Plates XXI, XXVI) has described and figured this species. The body is dorsoventrally compressed, the tail has a circular transverse section. Thorn-like scales cover the surface. The lateral line extends along the narrow lateral margin of the body, and is continued on the tail. It appears as a distinct lateral furrow. The margins of this furrow bear fringes. In the furrow itself a row of bud-like protuberances is observed. Above and below each one of these a lobular excrescence with fringed margin is met with. The fringes of the margins of the furrow and the lobes are composed of filiform parts, richly pigmented and dark in color. Garman's description and illustrations of the bud-like protuberances are insufficient. He mentions them only from the lateral line and the symphysis below the mouth. Closer inspection shows that they also occur on the head. There are on each side (text figs. 1, 2): in the lateral line (furrow) of the body 12 ventral (v); between the 9 and 10 of the lateral line, one above the other, 2 lateral (l); in the lateral line of the tail 12 caudal (c); in a horizontal row behind the corner of the mouth 4 mandibular (m); in a line parallel to and above the preceding one 7 maxillary (x); between the 4 organs of the two last named rows 1 inframaxillary (i); and on the lower jaw 4 inframandibular (n); together 84 bud-like organs.

The bud-like organs are cream colored, button-shaped, and composed of a short, stout, cylindrical peduncle only 70 μ long and on a semispherical head 400–500 μ in diameter. The histological structure of these organs can best be made out in longitudinal, axial sections (Fig. 3). The corium is very highly developed and covered by a pavement epithelium with large nuclei as in other parts of the skin. It forms two different kinds of papillae. In the one the corium predominates and the epithelium is only slightly developed,

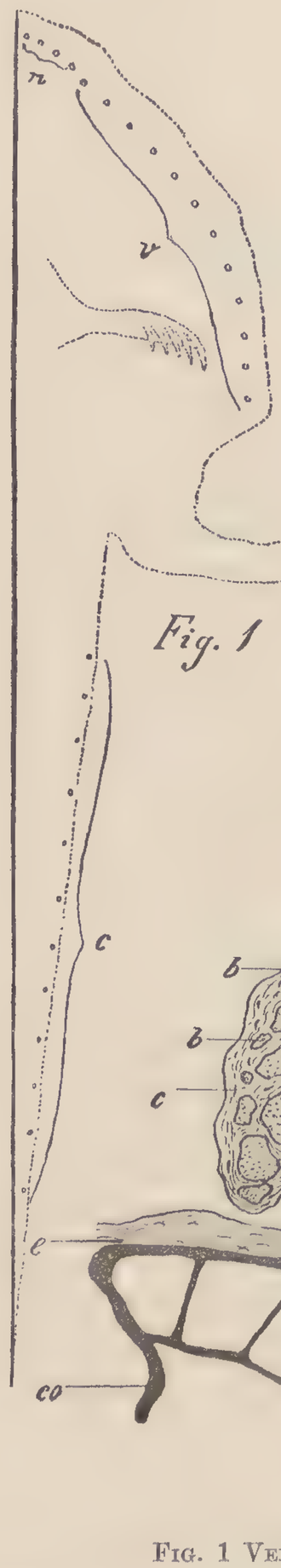

Fig. 1

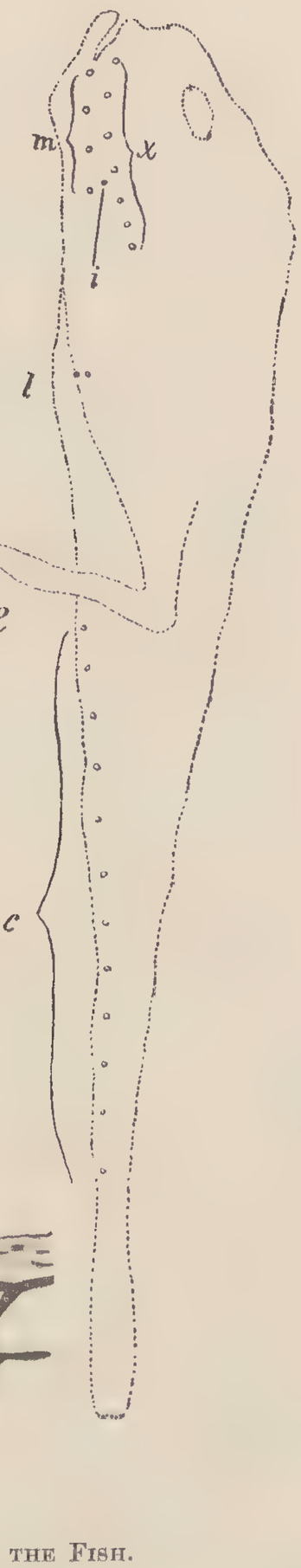

Fig. 2

Fig. 3

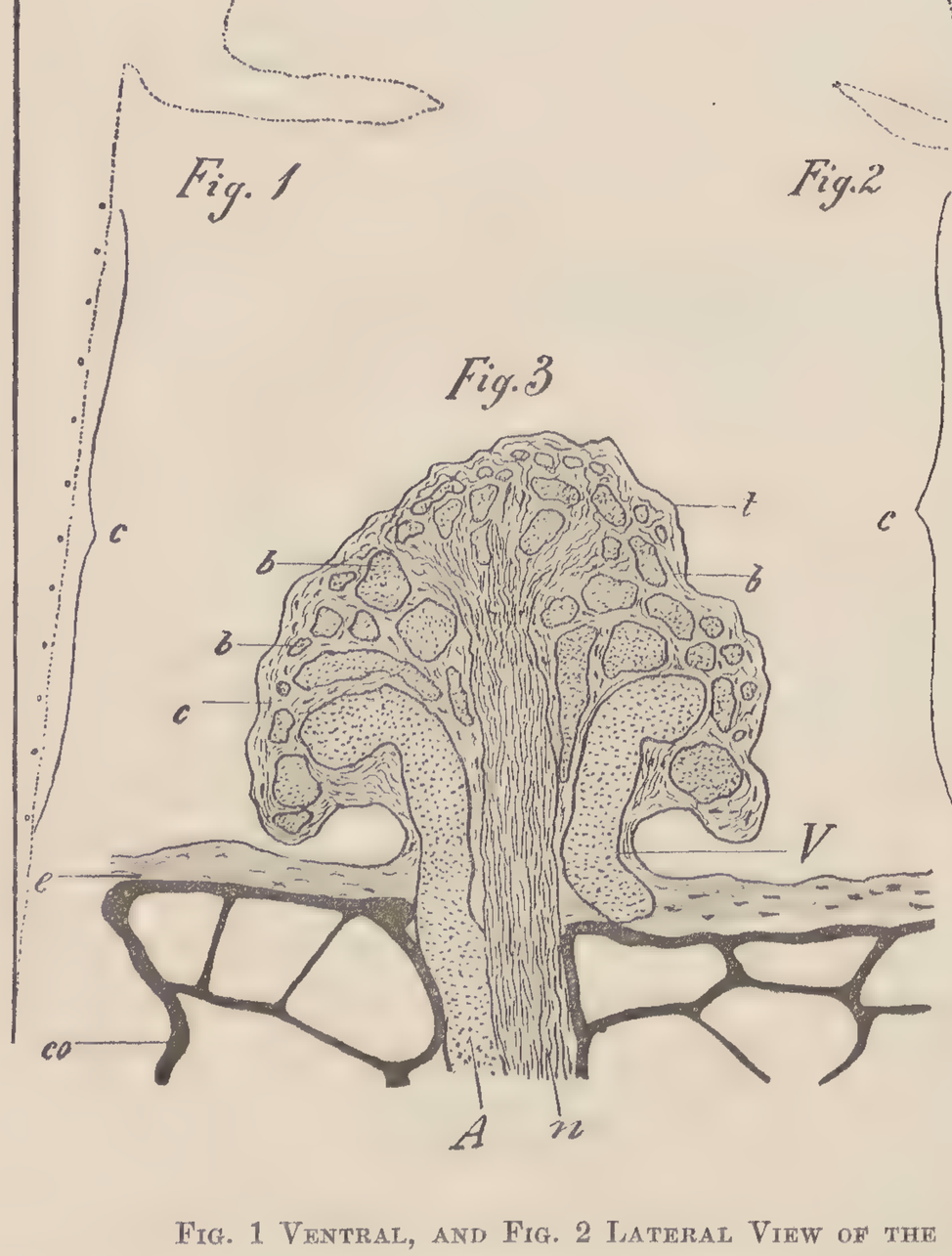

FIG. 1 VENTRAL, AND FIG. 2 LATERAL VIEW OF THE FISH.

Natural size. x, maxillar; i, inframaxillar; m, mandibular; n, inframandibular; v, ventral; l, lateral; c, caudal bud-like organs.

FIG. 3. AXIAL SECTION THROUGH A BUD-LIKE ORGAN.

Magnified 1 : 125. A, artery; V, vein; b, capillary blood vessels; c, connective tissue; co, corium; e, pavement epithelium; n, nerve; t, cuticle.

in the other the reverse is the case. The papillae of the first kind are very numerous, they form the "scales"; those of the second are less numerous and smaller, they form the basal parts, that is, the peduncles of the bud-like organs here described. Each bud-like organ is supplied with a nerve about 70 μ thick (Fig. 3 n) which traverses the layers of the corium. These layers bend outward around it and thus form a tubule. Besides the nerve also the artery passes through this tube. The terminal thickened part, the head of the organ, consists principally of spindle-shaped connective-tissue cells with oval nuclei (Fig. 3 c) and blood vessels (Fig. 3 b). On entering the organ the artery (Fig. 3 A) immediately divides to form a capillary network. These capillaries decrease in width from the centre towards the periphery; the narrowest are 12 μ wide. The capillaries unite to form a vein (Fig. 3 v) which has the same width as the artery. This vein extends for a considerable distance subcutaneously and does not pass through the tube in which the nerve and the artery are contained. The branching of the nerve commences at a higher level than the branching of the artery, above the centre of the head. Its proximal parts bear no branches. Just beyond the centre of the head it splits up into several bundles of primitive fibres. These ramify and thus a mass of separate nerve fibres are produced, interlacing with the capillary blood vessel net which is densest at the apex of the organ. The final termination of the nerves could not be made out, on account of the specimen not being specially preserved for the purpose. A continuous cuticle covers the whole organ (Fig. 3 t).

Organs comparable to these have been described by F. Leydig (1850, p. 172, 1851, pp. 235–239) as "Nervenknöpfe." These differ, however, in several respects from the bud-like organs of Malthopsis examined by me. The differences in shape and size would not be important; but the cylinder epithelium which forms a principal part of the "Nervenknöpfe," and to which the authors attach so great an importance, is missing in the buds of Malthopsis. If we were to imagine the organs of Malthopsis covered by a sensitive cylinder epithelium they would be "Nervenknöpfe," still, however, differing from those described by F. Leydig (l. c.) in some respects. Leydig found the "Nervenknöpfe" always in slime canals; whilst the organs of Malthopsis, are free. The "free lateral organs" described by F. E. Schulze (1870, p. 71), which might also be compared to the buds of Malthopsis, are superficial swellings in the floor of the lateral canals. According to B. Solger (1880, Plate XVI, Fig. 6) they are oval plates. Thus these organs also differ considerably from those of Malthopsis. Neither can the "Nervenknöpe" of *Lepidoleprus coelorhynchus* (Leydig 1850, pp. 235–239) be compared with them. The term "Nervenknöpfe" is hardly applicable to the organs of Malthopsis because their heads are not endswellings of nerves, but composed of connective tissue and abundant blood vessels. In so much as they are richly

innervated distally, they correspond to the "Nervenknöpe" of *Acerina cernua*, but Leydig (1879, p. 163) says concerning these that the connective tissue of the swelling, which surrounds the nerves and blood vessels is tender, nearly gelatinous. It seems therefore that they do not belong to the class of structures designated as "Nervenknöpfe." The essential difference, the absence of a cylinder epithelium in the buds of Malthopsis, can in so far not be relied upon, as it may be present in the living fish and absent in the specimen examined only because it has fallen off on account of its perishable nature; the circumstances however that the organs are entirely surrounded by a cuticle and that the tender and perishable sensitive epithelium would, if present, be coverless and exposed, make it appear improbable that such is the case.

Concerning the physiological function of the organs it must be borne in mind that they must either be radiating or sensory, because so rich an innervation must have some purpose. The general appearance of the organs, their semispherical shape and the abundance of connective tissue in them are in favor of the latter view and make it probable that the function performed by them is the perception of hydrostatic pressure, a knowledge of which must be of great importance to any fish able to live only within certain bathymetrical limits.

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Plate 1.

Figs. 1, 2. Malthopsis spinulosa Garman.

Fig. 1. The ventral side of a specimen. Drawing; slightly reduced; o, doubtful bud-like marginal organs.

Fig. 2. Ventral side of the left half of a specimen. Photograph; slightly magnified; o, doubtful bud-like marginal organs.

Figs. 3–5. Ipnops agassizii Garman.

Fig. 3. The head seen from above. Drawing; natural size; d, radiating discs.

Fig. 4. The head seen from above. Photograph; slightly magnified; d, radiating discs.

Fig. 5. The fish seen from the side. Drawing; natural size; d, radiating disc.

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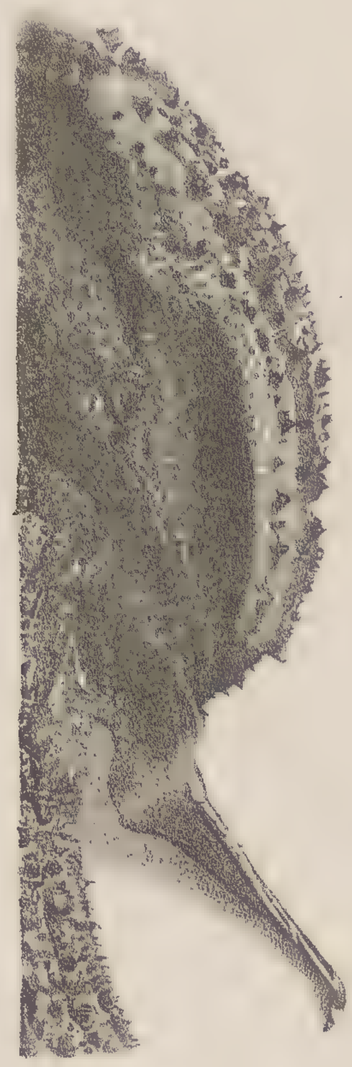

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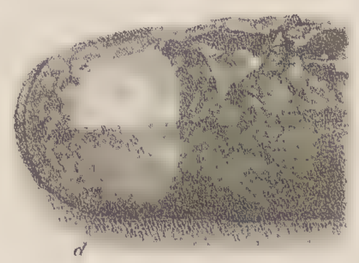

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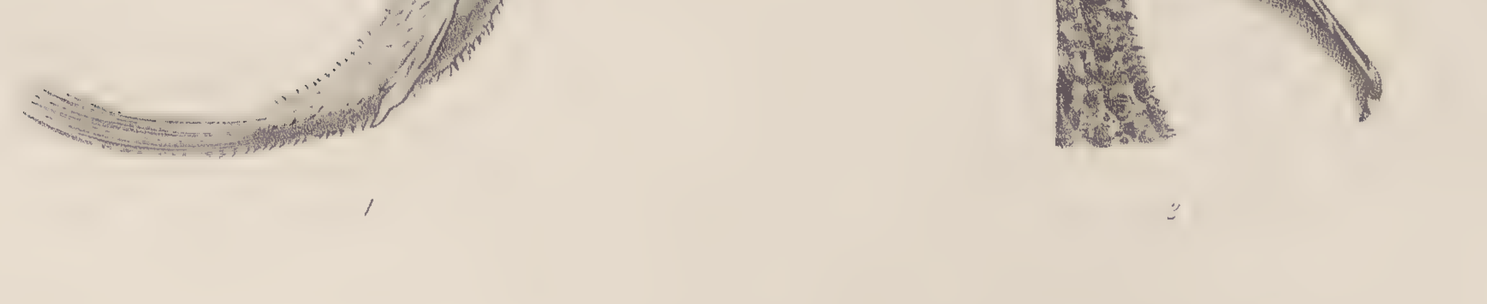

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12 MALTHOPSIS SPINULOSA Garm

PLATE 2.

Plate 2.

Figs. 6–9. Malthopsis spinulosa Garman.

Fig. 6. The head in three quarter profile. Drawing; natural size; o, doubtful bud-like marginal organs; te, frontal tentacular papilla.

Fig. 7. Part of a transverse section of the interior of one of the ventral lobes of the distal trilobed part of the frontal tentacular papilla. Stained: haematoxylin-picric acid-fuchsin. Drawing. c, connective-tissue septa between the longitudinal chambers; cv, lumina of the glandular tubes; pc, walls of the glandular tubes composed of cylindrical cells.

Fig. 8. Transverse section of the distal trilobed part of the frontal tentacular papilla. Stained: haematoxylin-picric acid-fuchsin. Photograph, magnified 1 : 41. b, peripheral blood vessels; b′, large central sinuous blood vessel; c, connective-tissue septa between the longitudinal chambers; cv, lumina of the glandular tubes; m, muscles; p, groups of pigment cells; pc, walls of the glandular tubes composed of cylindrical cells; s, longitudinal strands of semicartilaginous tissue.

Fig. 9. Transverse section of the distal trilobed part of the frontal tentacular papilla. Stained: haematoxylin-picric acid-fuchsin. Drawing, magnified 1 : 41. b, peripheral blood vessels; b′, large central sinuous blood vessel; c, connective-tissue septa between the longitudinal chambers; cv, lumina of the glandular tubes; m, muscles; p, groups of pigment cells; pc, walls of the glandular tubes composed of cylindrical cells; s, longitudinal strands of semicartilaginous tissue.

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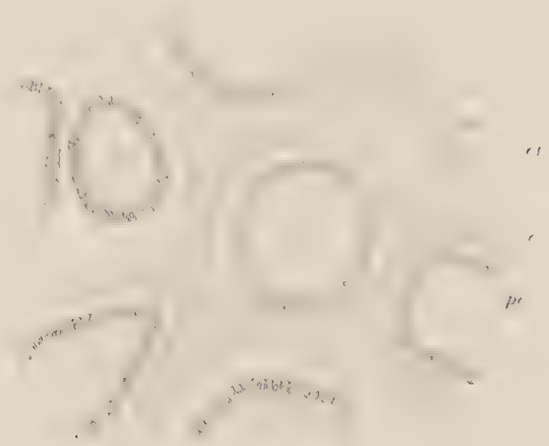

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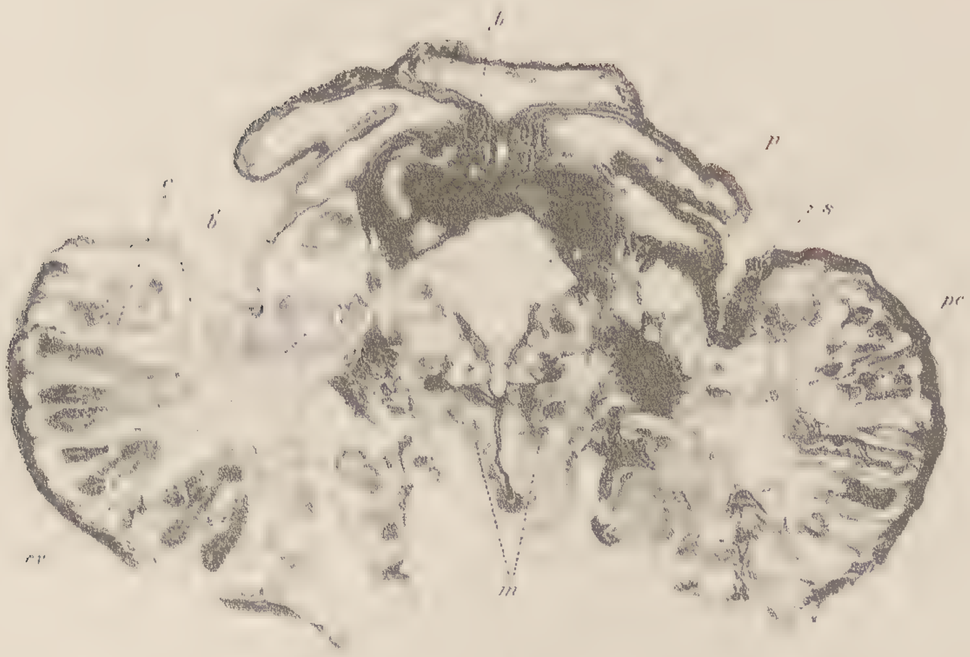

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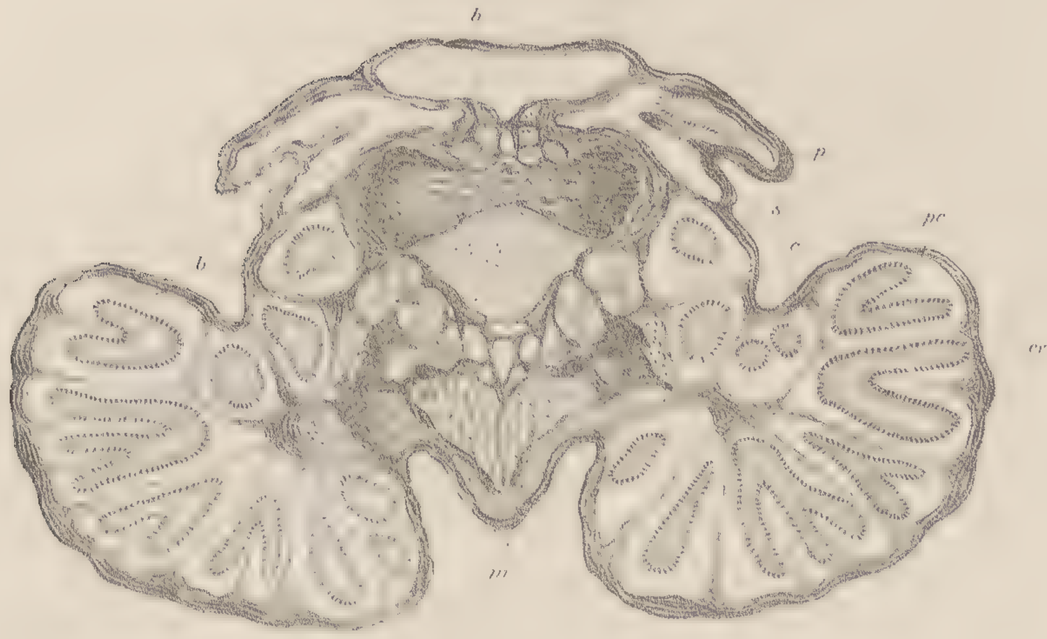

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PLATE 3.

Plate 3.

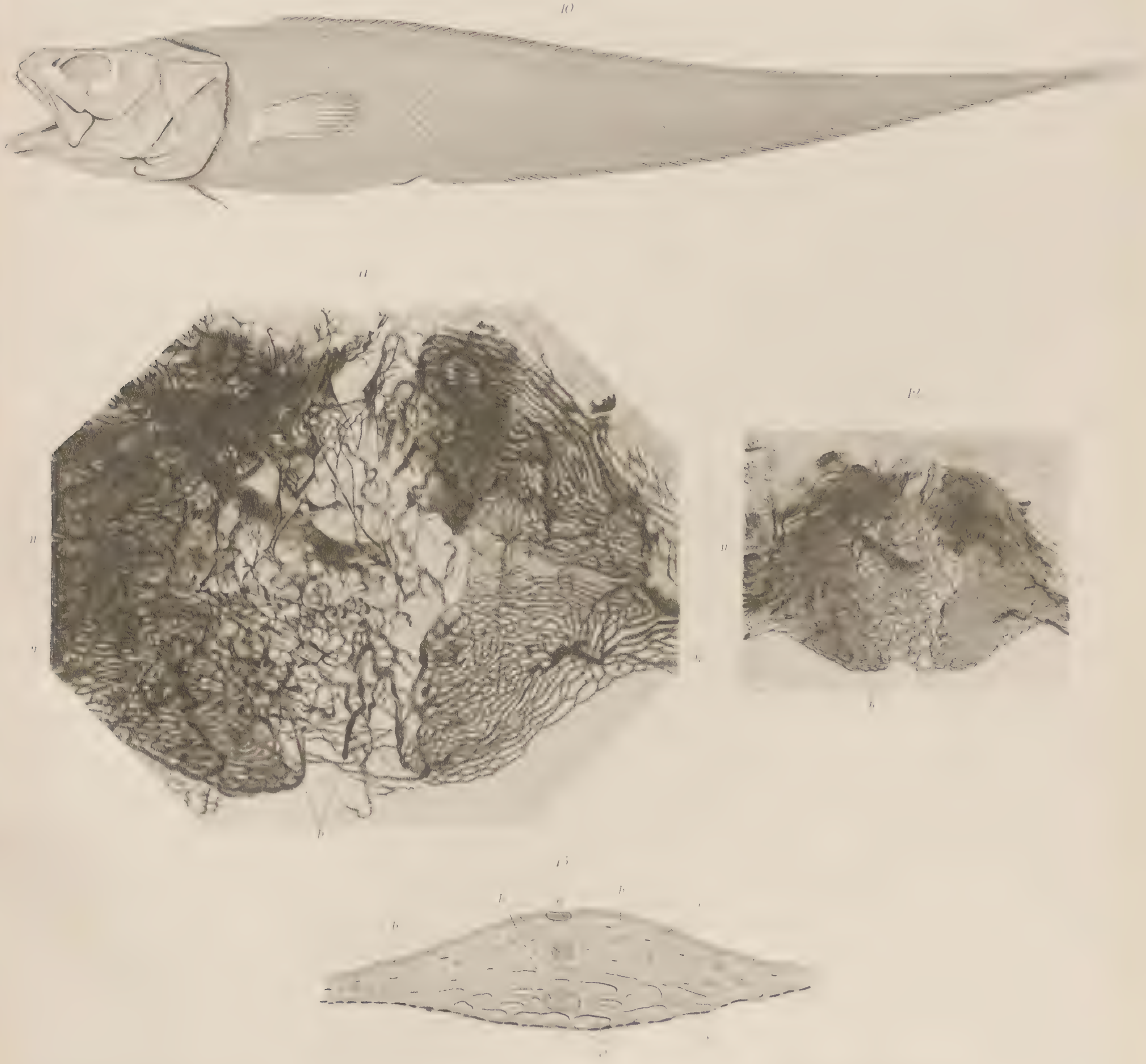
Figs. 10–13. Leucicorus lusciosus Garman.

Fig. 10. The fish seen from the side. Drawing; natural size.

Fig. 11. A radiating disc in transmitted light. Photograph; magnified 1 : 41. b, blood vessel; n, main disc nerve; n′, smaller accessory disc nerves.

Fig. 12. A radiating disc in transmitted light. Photograph, magnified 1 : 21. b, blood vessels; n, main disc nerve; n′, smaller accessory disc nerves.

Fig. 13. Transverse section of a radiating disc. Stained: haematoxylin. Drawing; magnified 1 : 42. b, blood vessels; c, paratangentially arranged connective-tissue cells; cv, cavities in the basal part of the radiating disc; n′, small accessory disc nerve; p, pigment cells.



10-13 Leucicorus lusciosus Garman

PLATE 4.

Plate 4.

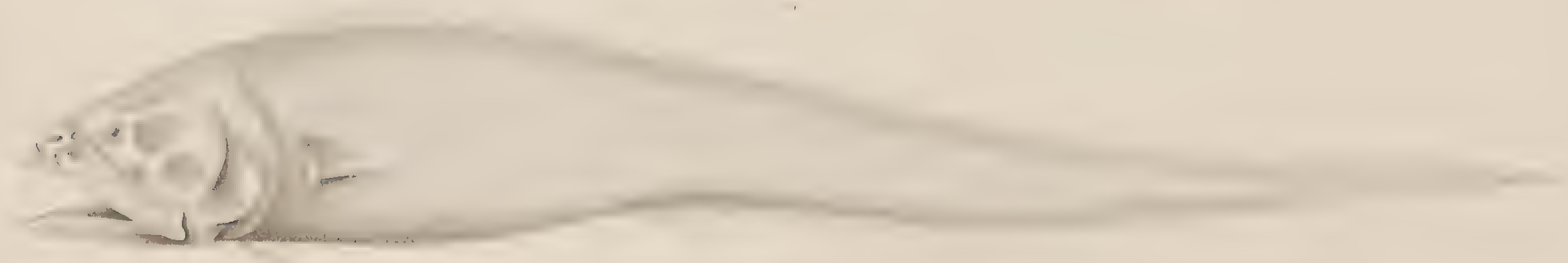
Fig. 14–17. Bassozetus nasus Garman.

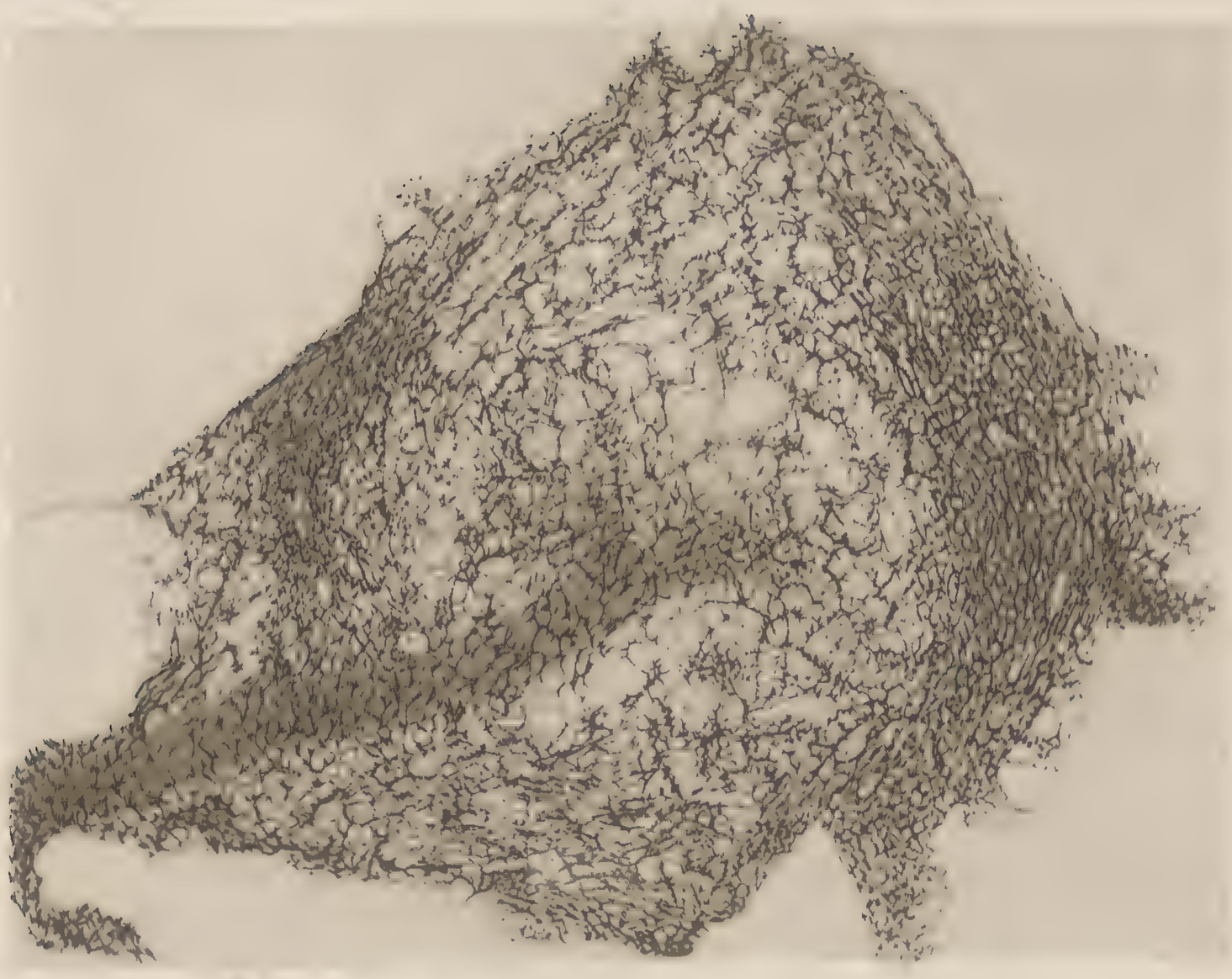
Fig. 14. The fish seen from the side. Drawing; natural size.

Fig. 15. A radiating disc in transmitted light. Photograph; magnified 1 : 58. n, main disc nerve; p, reticulation formed by the pigment cells with their long processes.

Fig. 16. A radiating disc in transmitted light. Photograph; magnified 1 : 27. n, main disc nerve; p, reticulation formed by the pigment cells with their long processes.

Fig. 17. Transverse section of a radiating disc. Stained: haematoxylin. Drawing; magnified 1 : 42. b, blood vessels; c, paratangentially arranged connective-tissue cells; n, main disc nerve; p, basal pigment cells.





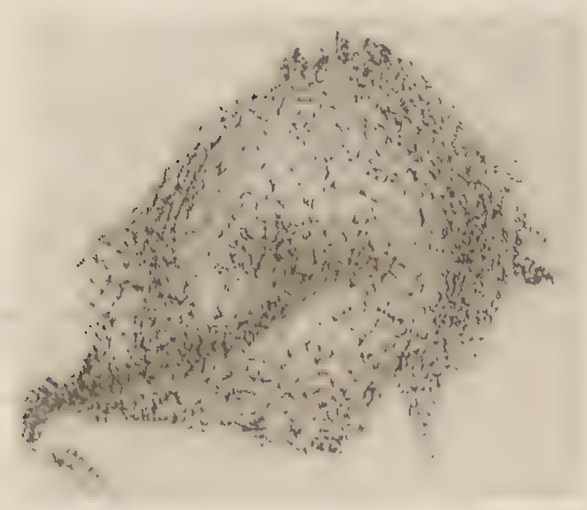


PLATE 5.

Plate 5.

Figs. 18–20. Macrurus canus Garman.

Fig. 18. The fish seen from the side. Drawing; natural size.

Fig. 19. A radiating disc in transmitted light. Photograph; magnified 1 : 41. n, main disc nerve; p, branched pigment cells.

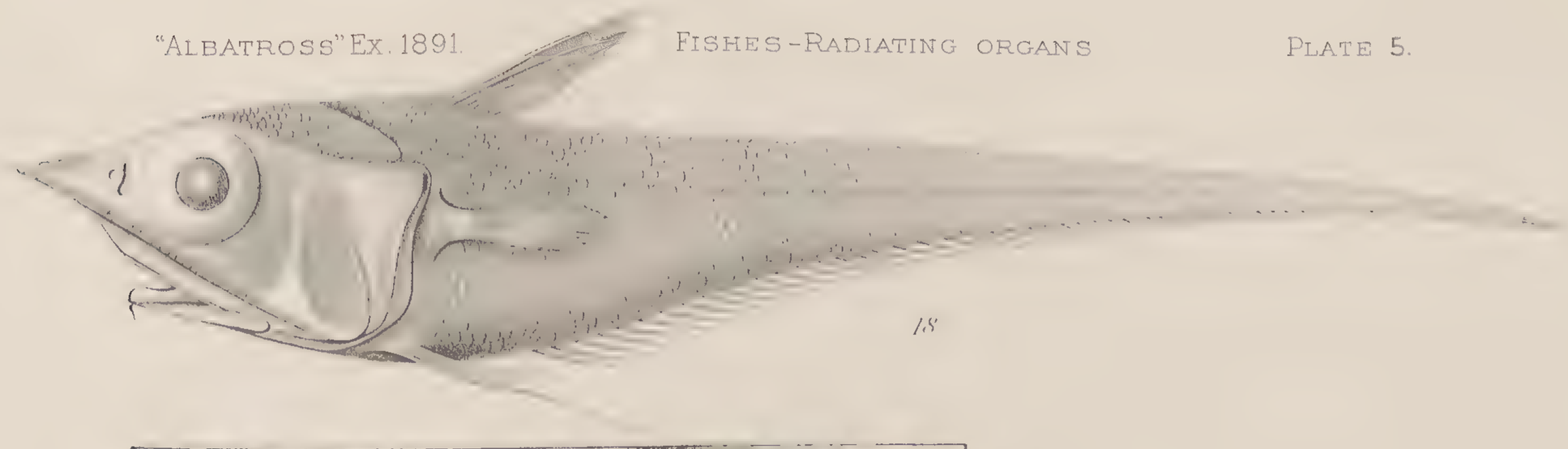
Fig. 20. A radiating disc in transmitted light. Photograph; magnified 1 : 17. n, main disc nerve; p, branched pigment cells.

Figs. 21–23. Myctophum aurolaternatum Garman.

Fig. 21. The fish seen from the side. Drawing; natural size. al, anterior lateral radiating organs; ma, mandibular radiating organs; ml, mediolateral radiating organs; op, opercular radiating organs; pe, pectoral radiating organs; pl, posterior lateral radiating organs; va, anterior ventroanal radiating organs; vc, ventrocaudal radiating organs; ve, ventromedial radiating organs; vp, posterior ventroanal radiating organs.

Fig. 22. The fish seen from below. Drawing; natural size. al, anterior lateral radiating organs; ma, mandibular radiating organs; ml, mediolateral radiating organs; op, opercular radiating organs; pe, pectoral radiating organs; pl, posterior lateral radiating organs; va, anterior ventroanal radiating organs; vc, ventrocaudal radiating organs; ve, ventromedial radiating organs; vp, posterior ventroanal radiating organs.

Fig. 23. Axial section vertical to the median plane of the fish through a posterior lateral radiating organ. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 140. b, blood vessels; c, connective tissue of the interior of the organ; p, section through the outer horseshoe-shaped pigment cell band; pc, radiating cells; pp, internal pigment cell layer; si, scale underlying the radiating organ; ss, scale covering the radiating organ; t, section through the H-shaped thickening of the covering scale.



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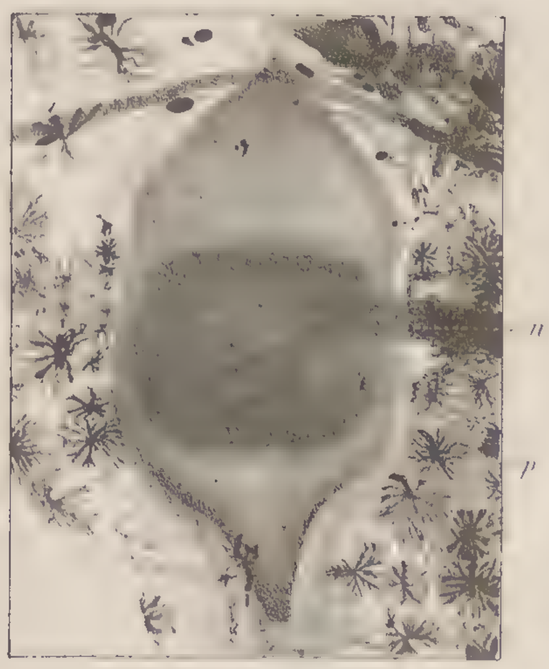

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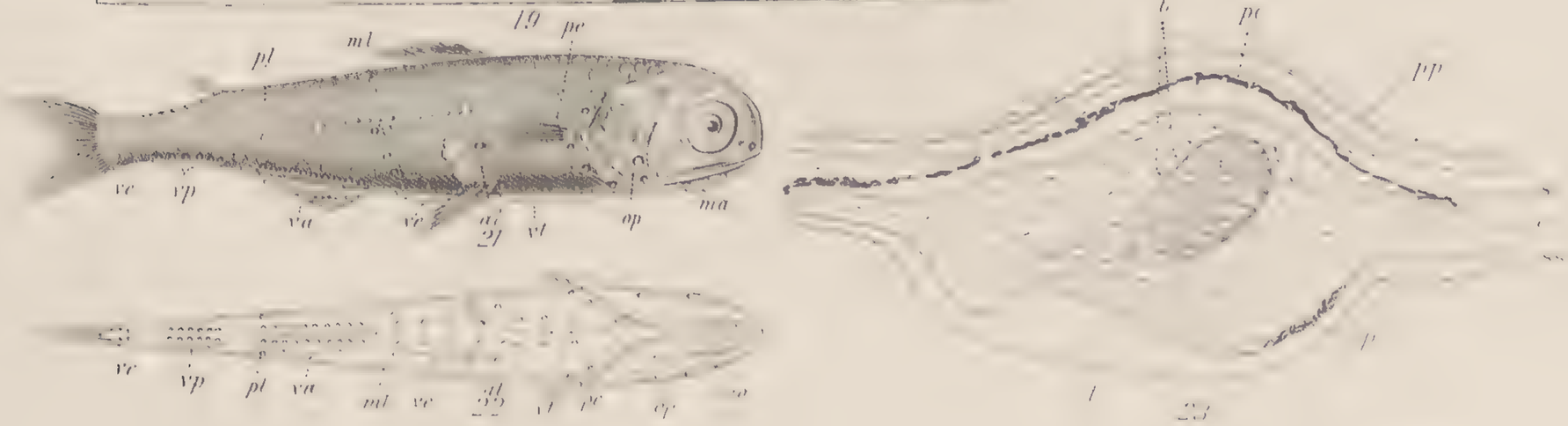

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B Meisel, lith Boston

18-20 MACRURUS CANUS Garm. 21-23 MYCTOPHUM AUROLATERNATUM Garm

PLATE 6.

Plate 6.

Figs. 24, 25. Argyropelecus lychnus Garman.

Fig. 24. Axial section vertical to the median plane of the fish through an anterior lateral radiating organ. Stained: picric acid-carmin. Drawing; magnified 1 : 84. A, proximal oval part of the organ; B, zigzag fibres of the reflecting layer; C, constriction between the proximal and distal part of the organ; D, distal paraboloidal part of the organ; g, inner region; l, middle region; p, pigment sheath; r, reflecting layer; s, outer region.

Fig. 25. The fish seen from the side. Drawing; natural size. a, anal radiating organs; al, anterior lateral radiating organs; ao, anteorbital radiating organs; br, branchiostegal radiating organs; ml, medial lateral radiating organs; op, opercular radiating organs; pc, pectoral radiating organs; po, postorbital radiating organs; vc, ventrocaudal radiating organs; ve, ventromedial radiating organs; vt, ventrothoracic radiating organs.

Figs. 26, 27. Sternoptyx obscura Garman.

Fig. 26. The fish seen from the side. Drawing; natural size. a, anal radiating organs; al, anterior lateral radiating organs; br, branchiostegal radiating organs; op, opercular radiating organs; pl, posterior lateral radiating organs; vc, ventrocaudal radiating organs; ve, ventral radiating organs; vt, ventrothoracic radiating organs.

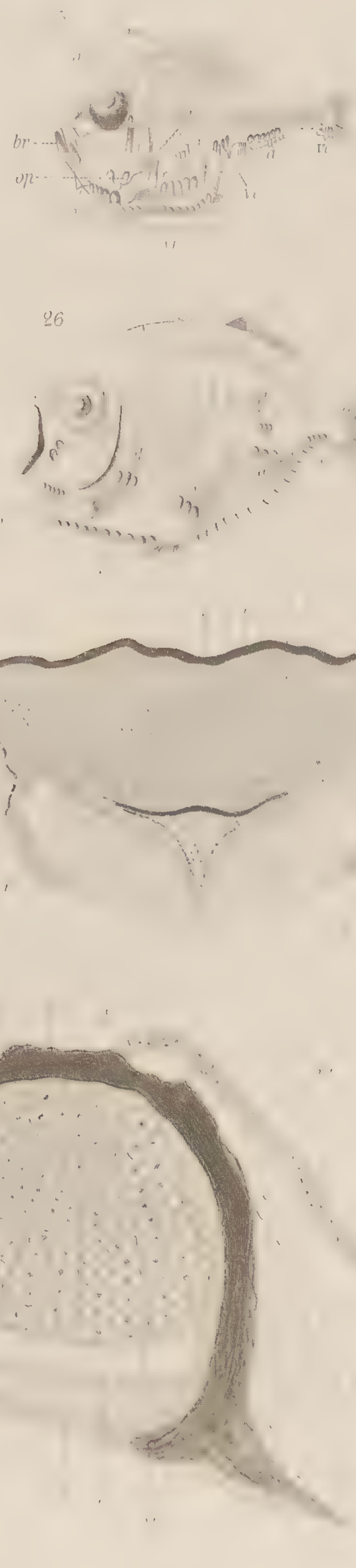
Fig. 27. Axial section vertical to the median plane of the fish through a ventrothoracic radiating organ. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 42. g, inner region; gl, gelatinous tissue occupying the distal part of the organ; l, middle region; p, pigment sheath; r, reflecting layer; s, outer region.

Figs. 28–30. Cyclothone acclinidens Garman.

Fig. 28. The fish seen from the side. Drawing; natural size. a, ventroanal radiating organs; ve, ventromedial radiating organs; vt, ventrothoracic radiating organs.

Fig. 29. The fish seen from below. Drawing; natural size. a, ventroanal radiating organs; br, branchiostegal radiating organs; ve, ventromedial radiating organs; vt, ventrothoracic radiating organs.

Fig. 30. Axial section vertical to the median plane of the fish through a ventrothoracic radiating organ. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 520; b, blood vessel leading to the organ; c, connective-tissue capsule within the pigment sheath; cd, transparent connective tissue forming the superficial covering of the organ in the orifice of the pigment sheath; cr, distal part of the connective-tissue capsule covering the mass of radiating cells outside; l, cylindrical cells of the outer zone; m, central part of the organ composed of small irregularly arranged polyedrical cells; p, pigment sheath; r, outer part of the organ composed of cells arranged in regular rows; t, transparent intermediate zone.



1-25 Argyropelecus lychnus Garm., 26,27 Sternoptux obscura [illegible]
28-30 Cyclothone acclinidens Garm

PLATE 7.

Plate 7.

Figs. 31–37. Lychnopoles argenteolus Garman.

Fig. 31. The fish seen from the side. Drawing; natural size. a, anal radiating organs; al, anterior lateral radiating organs; ao, anteorbital radiating organs; ml, medial lateral radiating organs; op, opercular radiating organs; pl, posterior lateral radiating organs; ve, ventromedial radiating organs; vt, ventrothoracic radiating organs.

Fig. 32. The fish seen from below. Drawing; natural size. a, anal radiating organs; al, anterior lateral radiating organs; ao, anteorbital radiating organs; ma, mandibular radiating organs; ml, medial lateral radiating organs; op, opercular radiating organs; pl, posterior lateral radiating organs; vs, ventromedial radiating organs; vt, ventrothoracic radiating organs.

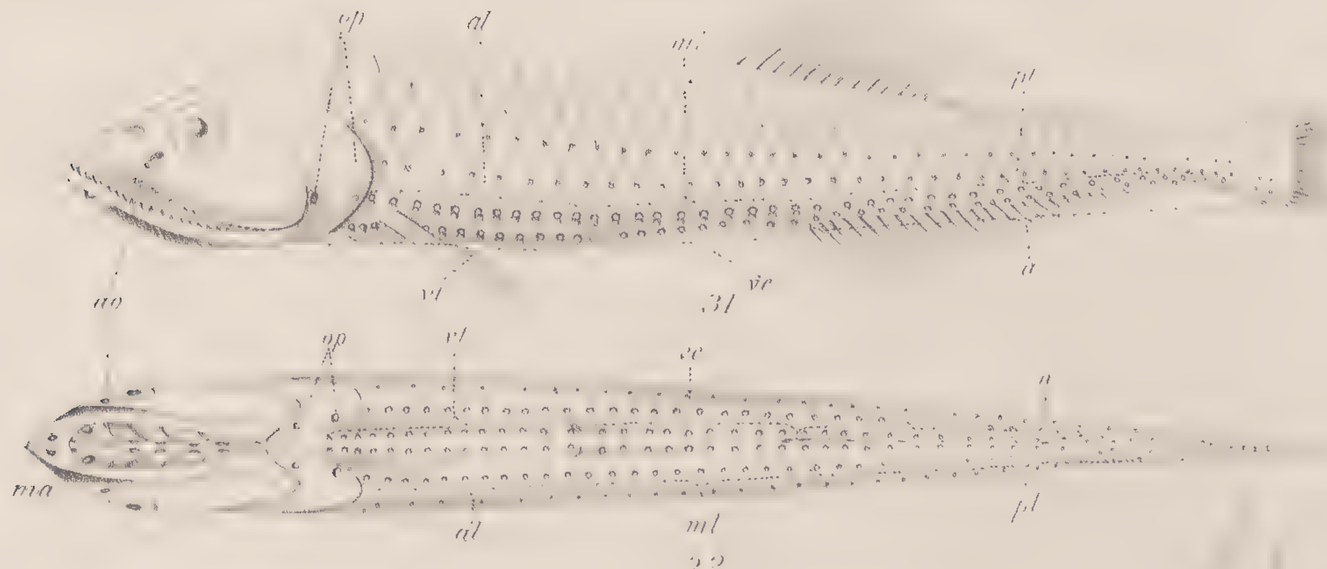
Fig. 33. The head of the fish with distended lower jaw seen from below. Drawing; natural size. br, branchiostegal radiating organs; g, guttural radiating organs; ma, mandibular radiating organs.

Fig. 34. Part of an axial section vertical to the median plane of the fish through a medial lateral radiating organ showing the outer region. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 180. c, connective-tissue membrane forming the walls of the facets; gl, gelatinous tissue occupying the distal part of the organ; o, cavity in the central part of the facets; sc, curved oblique cells in the proximal part of the facets; sp, straight longitudinal spindle-shaped cells in the distal part of the facets.

Fig. 35. Transverse section of the outer region of a medial lateral radiating organ. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 350. c, connective-tissue membrane forming the walls of the facets; o, cavity in the central part of a facet; p, pigment sheath; r, reflecting layer; sp, straight longitudinal spindle-shaped cells in the distal part of the facets.

Fig. 36. Part of an axial section vertical to the median plane of the fish through a medial lateral radiating organ showing part of a facet of the middle region in longitudinal section. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 700. c, connective-tissue membrane forming the wall of this facet; cn, slender axial canal in the facet; nu, nuclei of the cells; ph, only slightly stainable proximal portion of the cells; pt, highly stainable distal portion of the cells.

Fig. 37. Axial section vertical to the median plane of the fish through a medial lateral radiating organ. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 110. A, proximal spherical part of the organ; b, blood vessels outside the pigment sheath; C, constriction between the proximal spherical and the distal paraboloidal part of the organ; c, connective-tissue capsule lying within the reflecting layer; cc, tubular cavity in the axial portion of the proximal part of the organ; ci, radiating facets of the inner region of the organ; cm, radial facets of the inner part of the middle region; co, longitudinal facets of the outer part of the middle region; cr, outer connective-tissue sheath of the organ; D, distal paraboloidal part of the organ; g, inner region of the organ; gl, gelatinous superficial portion of the tissue occupying the distal part of the organ; gr, granular basal portion of the tissue occupying the distal part of the organ; l, middle region of the organ; p, pigment sheath; r, reflecting layer; s, outer region of the organ.



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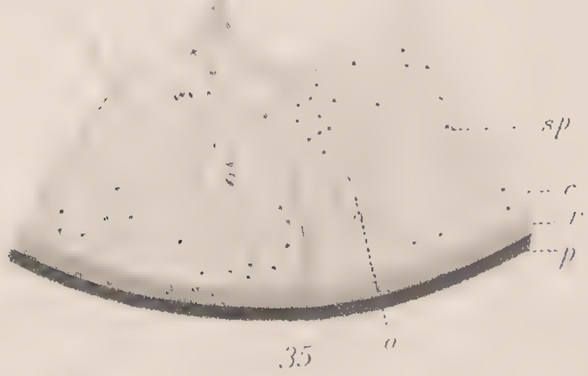

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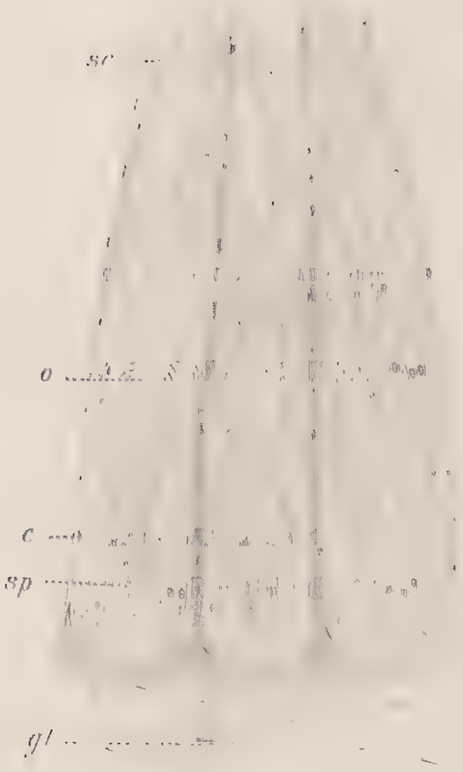

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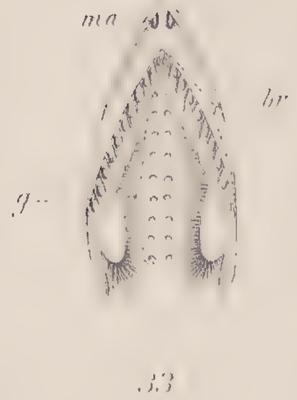

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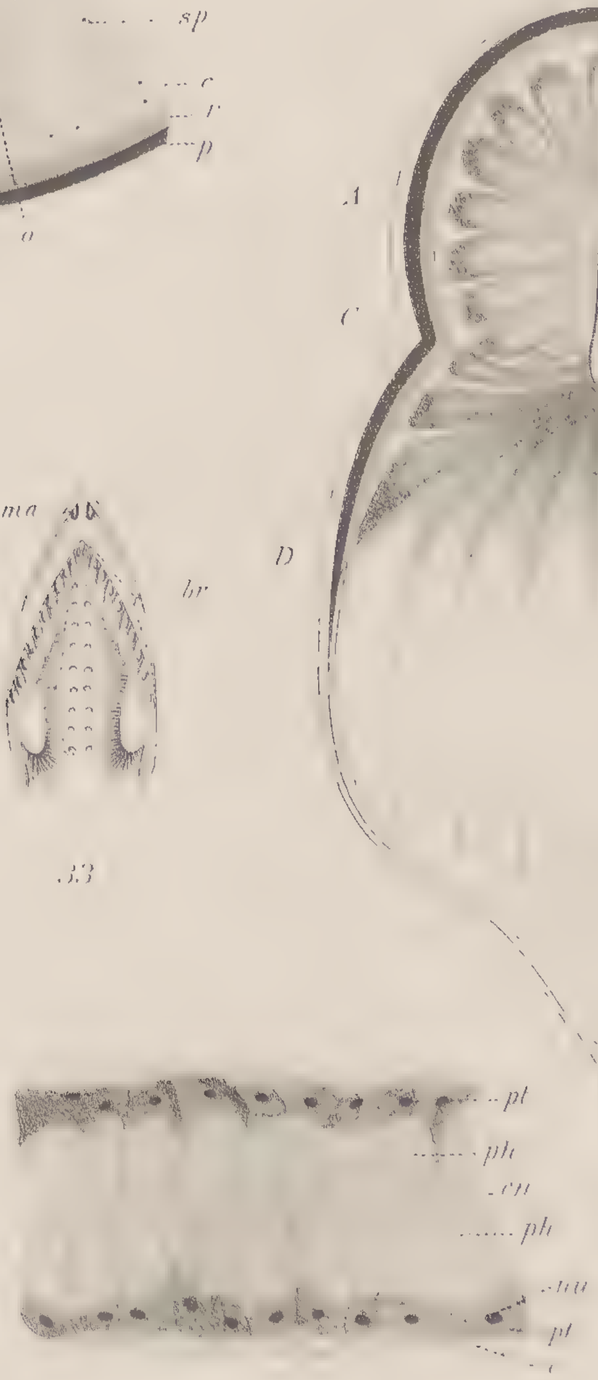

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31-37 LYCHNOPOLES ARGENTEOLUS Garm

PLATE 8.

Plate 8.

Figs. 38–40. Chauliodus barbatus Garman.

Fig. 38. The fish seen from the side. Drawing; natural size. a, ventroanal compound radiating organs; al, anterior lateral compound radiating organs; ao, anteorbital compound radiating organs; Ba, simple radiating organs with pigment sheath in the barbel; ml, medial lateral compound radiating organs; so, suborbital compound radiating organ; ve, ventromedial compound radiating organs; vt, ventrothoracic compound radiating organs; x, simple radiating organs with pigment sheath on the side of the head.

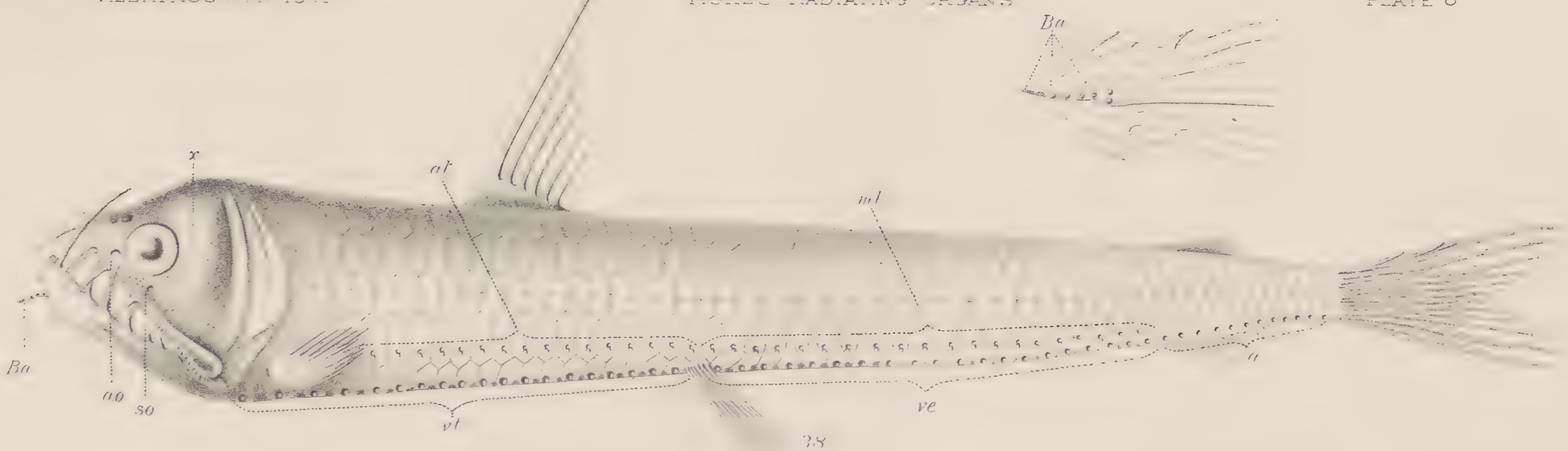
Fig. 39. The fish seen from below. Drawing; natural size. a, ventroanal compound radiating organs; al, anterior lateral compound radiating organs; Ba, simple radiating organs with pigment sheath in the barbel; g, guttural compound radiating organs; ml, medial lateral compound radiating organs; u, groups of simple radiating organs without pigment sheath; vc, ventromedial compound radiating organs; vt, ventrothoracic compound radiating organs.

Fig. 40. The lower jaw seen from below. Drawing; magnified 1 : 2; Ba, simple radiating organs with pigment sheath in the barbel.

Figs. 41, 42. Idiacanthus antrostomus Gilbert.

Fig. 41. The fish seen from the side. Drawing; natural size. a, ventroanal radiating organs with pigment sheath; al, anterior lateral radiating organs with pigment sheath; ml, medial lateral radiating organs with pigment sheath; pl, posterior lateral radiating organs with pigment sheath; so, suborbital radiating organ with pigment sheath; u, suborbital group of small radiating organs without pigment sheath; ve, ventromedial radiating organs with pigment sheath; vt, ventrothoracic radiating organs with pigment sheath.

Fig. 42. The fish seen from below. Drawing; natural size. a, ventroanal radiating organs with pigment sheath; g, guttural radiating organs with pigment sheath; ve, ventromedial radiating organs with pigment sheath; vt, ventrothoracic radiating organs with pigment sheath.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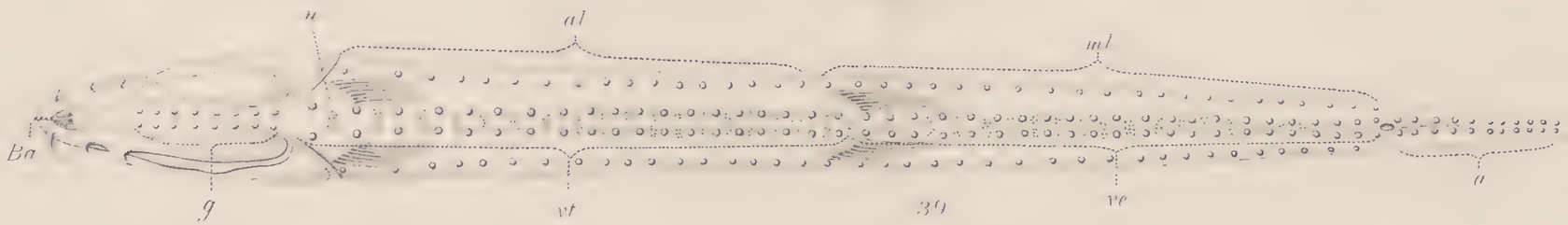
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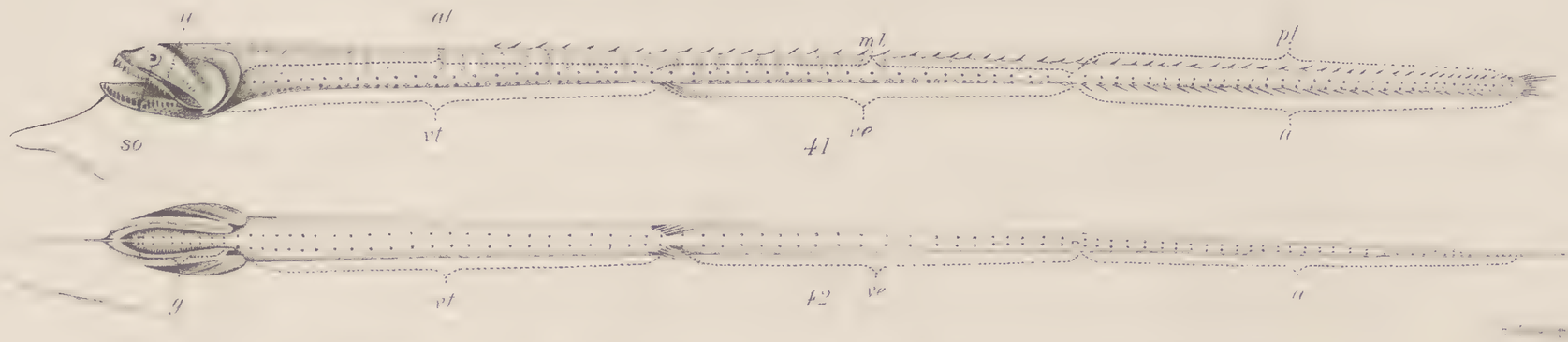
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PLATE 9.

Plate 9.

Figs. 43–46. Chauliodus barbatus Garman.

Fig. 43. Axial section vertical to the median plane of the fish through a regular simple radiating organ with pigment sheath. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 280. c, connective-tissue membrane forming the covering of the mass of radiating cells on the outer side; h, outer apparently structureless covering of organ; l, central mass of polyedrical cells; m, granular protoplasmic mass at the base of the organ; p, pigment sheath; pc, peripheral cylindrical radiating cells.

Fig. 44. Axial section vertical to the median plane of the fish through an irregular simple radiating organ with pigment sheath. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 280. c, connective-tissue membrane forming the covering of the mass of radiating cells on the outer side; h, outer, apparently structureless covering of organ; l, central mass of polyedrical cells; m, granular protoplasmatic mass at the base of the organ; p, pigment sheath; pc, peripheral cylindrical radiating cells.

Fig. 45. Axial section vertical to the median plane of the fish through a medial lateral compound radiating organ. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1: 140. A, proximal spherical part of the organ; a, mass of small cells in the central portion of the proximal spherical part of the organ; C, constriction between the proximal and distal parts of the organ; c, connective-tissue capsule within the pigment sheath; D, distal paraboloidal part of the organ; d, gelatinous connective tissue occupying the distal part of the organ; f, cells in the facets of the outer region; i, inner region; l, cells composing the middle region; m, middle region; o, outer region; p, pigment sheath; pc, large conic cells of the inner region; r, reflecting layer.

Fig. 46. Transverse section through the centre of the proximal spherical part of a medial lateral compound radiating organ. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 340. a, mass of small cells in the central portion of the proximal spherical part of the organ; b, blood vessels extending radially to the centre of the sphere; c, connective-tissue capsule; nu, nucleus of the conic cells; p, pigment sheath; ph, proximal only slightly stainable part of the conic cells; pt, peripheral highly stainable part of the conic cells.

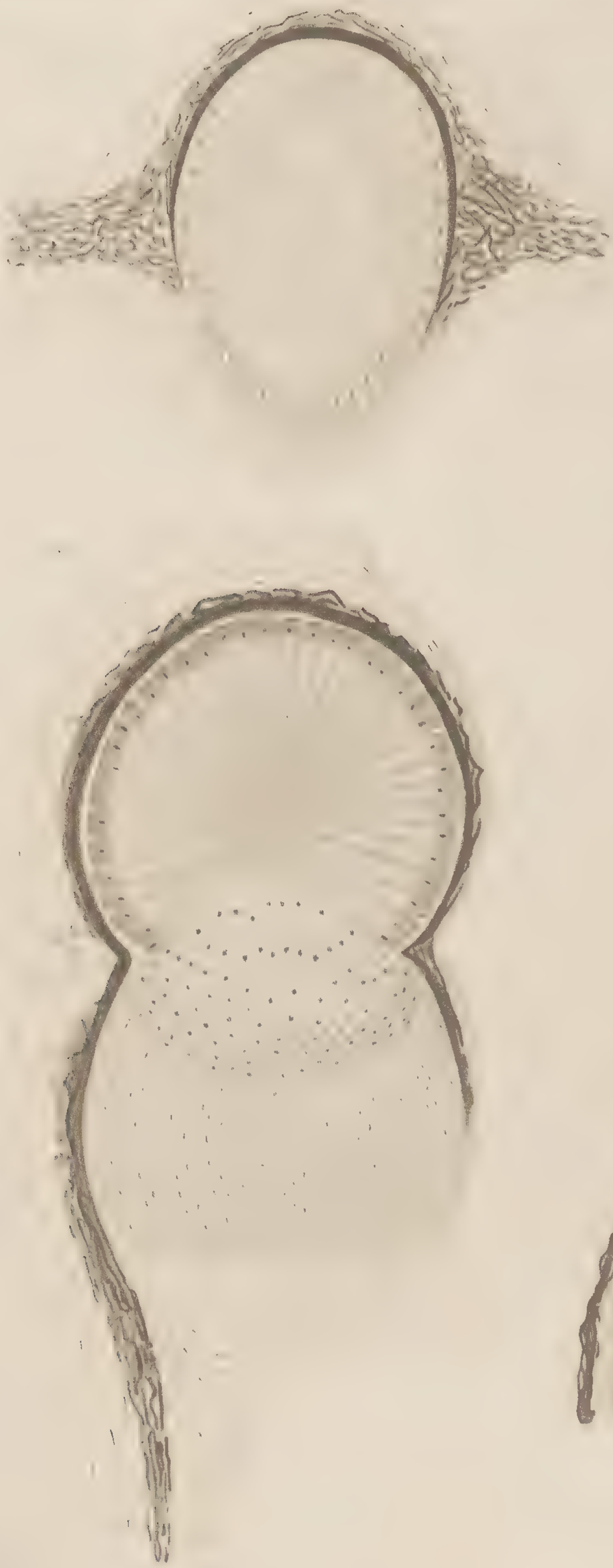


PLATE 10.

Plate 10.

Figs. 47–51. Stomias hexagonatus Garman.

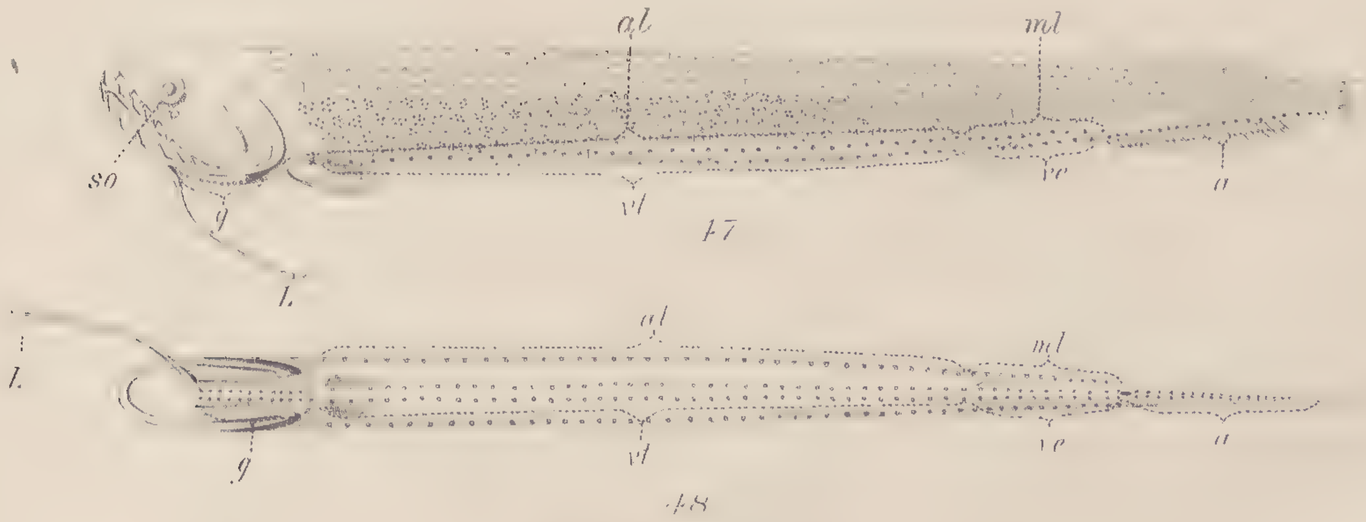
Fig. 47. The fish seen from the side. Drawing; natural size. a, ventrocaudal compound radiating organs; al, anterior lateral compound radiating organs; g, guttural compound radiating organs; L, radiating organ of the barbel; ml, medial lateral compound radiating organs; so, suborbital radiating organ; ve, ventromedial compound radiating organs; vt, ventrothoracic compound radiating organs.

Fig. 48. The fish seen from below. Drawing; natural size. a, ventrocaudal compound radiating organs; al, anterior lateral compound radiating organs; g, guttural compound radiating organs; ml, medial lateral compound radiating organs; ve, ventromedial compound radiating organs; vt, ventrothoracic compound radiating organs.

Fig. 49. Transverse section through the outer distal part of the cylindroconic plug-shaped part of a ventrothoracic compound radiating organ. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 280. cc, central facet of cylindroconic plug; pc, transverse sections of cells in the outer facets of the cylindroconic plug.

Fig. 50. Axial section transverse to the barbel through the radiating organ of the barbel. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 120. A, upper (dorsal) part of the organ; B, lower (ventral) part of the organ; b, blood vessel following the axial thread, and sinuous blood vessels in the lower chamber of the dorsal part of the organ; c, connective-tissue sheath inclosing the organ; cv, cavities in the upper part of the organ; p, dorsal pigment sheath; pc, large radial conic cells of the lower spherical part of the organ; pm, pigmented membrane traversing the upper part of the organ; pt, annular thickening of the pigment layer; z, axial thread in the lower spherical part of the organ.

Fig. 51. Axial section vertical to the medial plane of the fish through a ventrothoracic compound radiating organ. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 160. d, blood vessels in the septa between the conic cells of the proximal spherical part of the organ; c, connective tissue covering the distal part of the organ on the outer side; cc, central facet of cylindroconic plug forming the distal part of the organ; co, conic proximal end of the outer plug-shaped part of the organ; cy, cylindroconic plug-shaped outer part of the organ; p, pigment sheath; pc, longitudinally elongated cells in the outer facets of the plug-shaped distal part of the organ; ph, inner only slightly stainable part of the radiating conic cells in the proximal spherical part of the organ; r, annular reflecting membrane surrounding the plug-shaped distal part of the organ; s, annular cavity surrounding the plug-shaped distal part of the organ.



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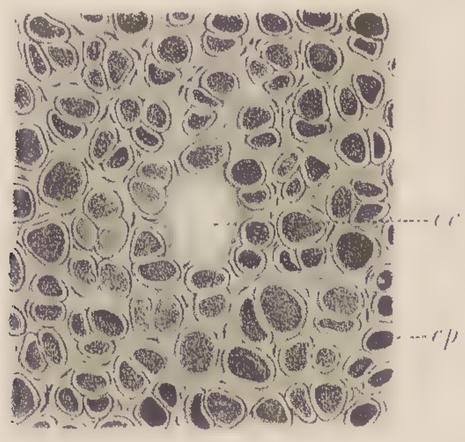

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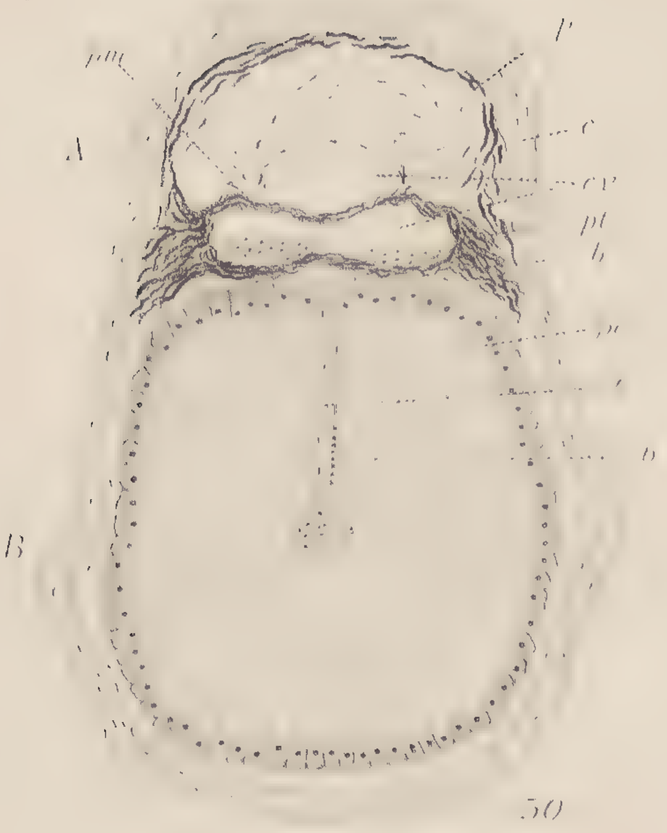

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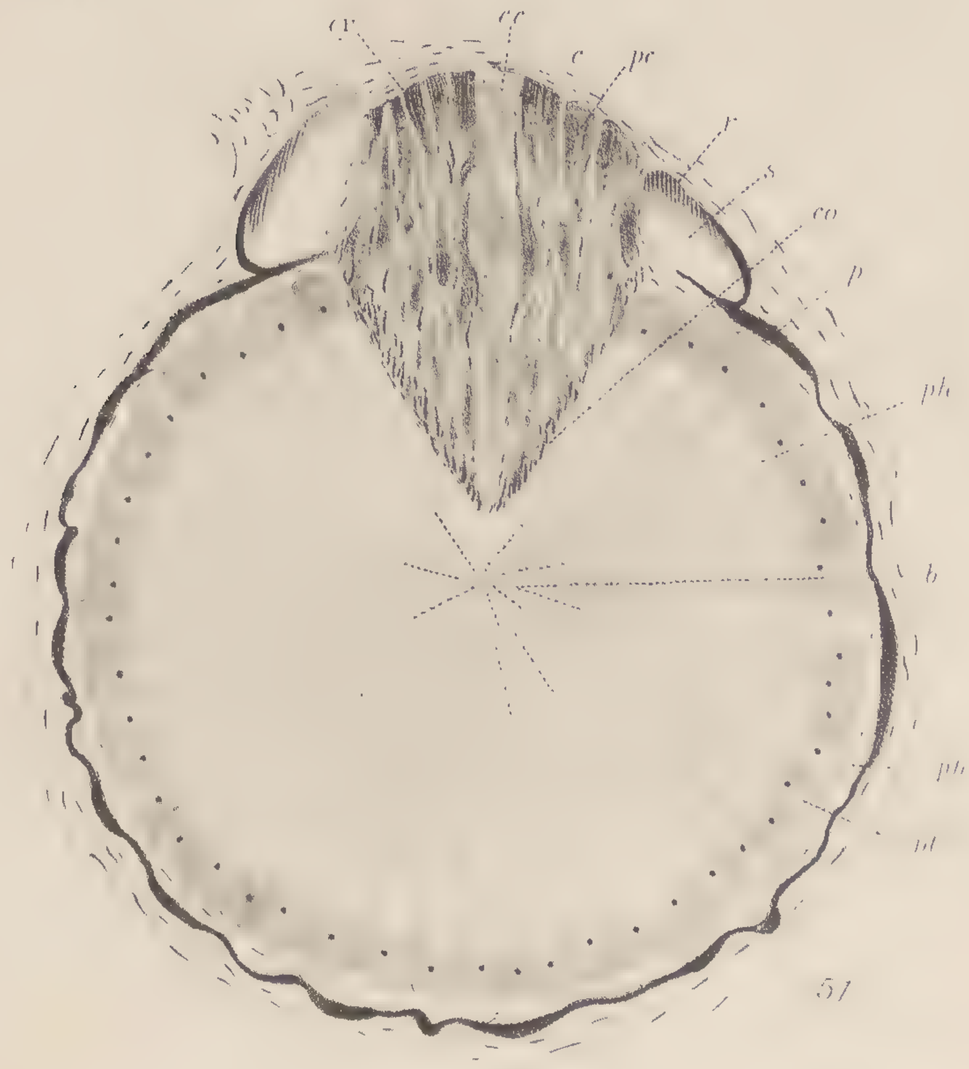

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48 to 51 STOMIAS HEXAGONATUS Garm

PLATE 11.

Plate 11.

Figs. 52–57. Halosaurus radiatus Garman.

Fig. 52. The fish seen from the side. Drawing; natural size.

Fig. 53. Radiating cephalic disc in transmitted light. Photograph; magnified 1 : 17. b′, large blood vessel leading to the disc; n, main disc nerve; n′, smaller accessory disc nerves.

Fig. 54. Radiating cephalic disc in transmitted light. Photograph; magnified 1 : 41. b′, large blood vessels leading to the disc; n, main disc nerve; n′, smaller accessory disc nerves.

Fig. 55. Radiating cephalic disc in transmitted light. Photograph; magnified 1 : 17. b′, large blood vessel leading to the disc; n, main disc nerve; n′, smaller accessory disc nerves.

Fig. 56. Transverse section through a cephalic radiating disc along its longer axis. Stained: haematoxylin-picric acid-fuchsin. Drawing; magnified 1 : 42. b, close capillary network of blood vessels underlying the cylinder cell layer; b′, large blood vessel leading to the disc; c, thickened connective tissue of the inner wall of the slime canal on which the cylinder cell layer rests; cv, cavity of slime canal; d, cylindrical cells of the radiating disc; m, marginal zone of the radiating disc; n, main disc nerve; s, outer wall of slime canal.

Fig. 57. Part of a transverse section through the cylinder cell layer of a cephalic radiating disc. Stained: haemotoxylin-picric acid-fuchsin. Drawing; magnified 1 : 200. b, close capillary network of blood vessels underlying the cylinder cell layer: c, thickened connective tissue of the inner wall of the slime canal on which the cylinder cell layer rests; d, cylindrical cells of the radiating discs.

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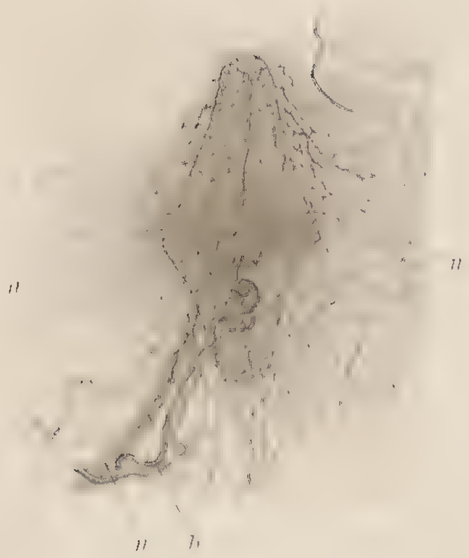

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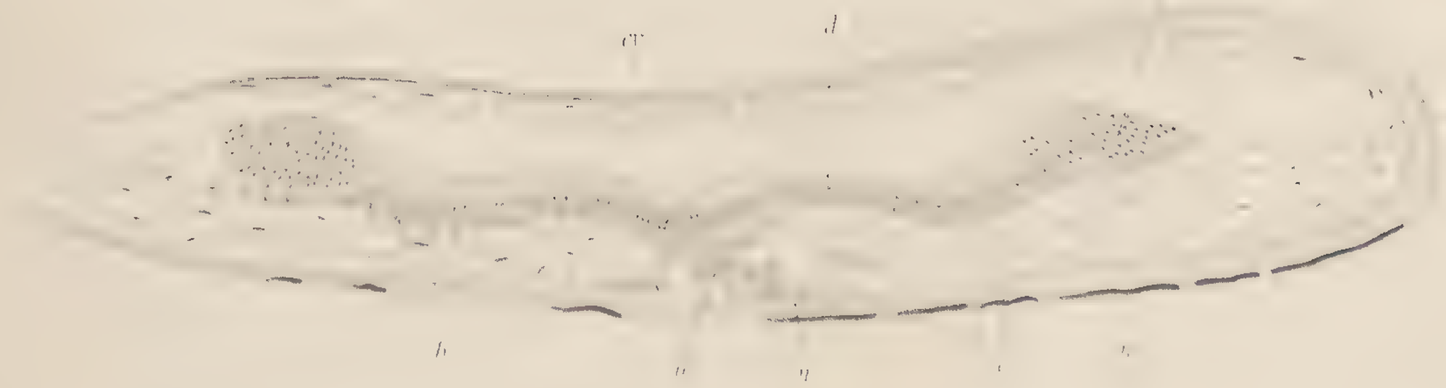

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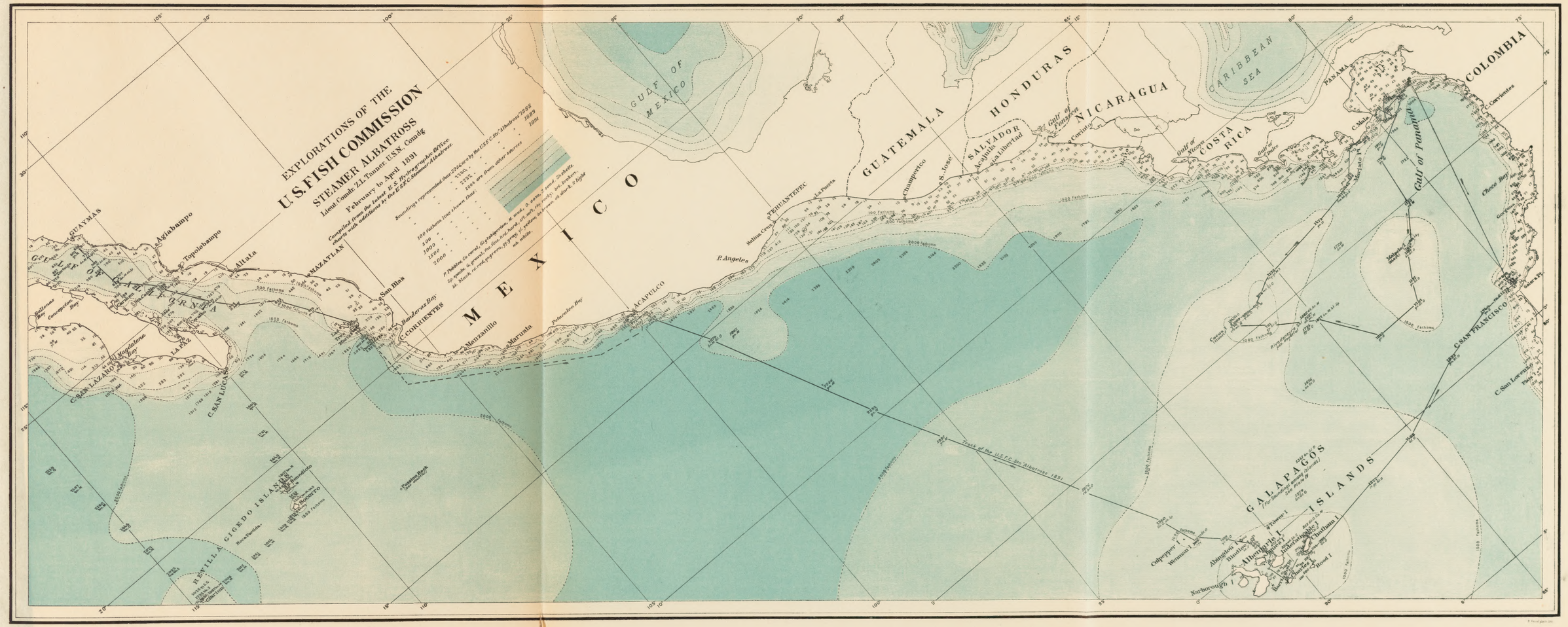
52 57 Halosaurus radiatus Garman.

PLATE 12.

Plate 12.

Hydrographic Sketch of the Pacific from the Gulf of California to Northern Ecuador, with the Track of the "Albatross," February 22 to April 23, 1891.


EXPLORATIONS OF THE
U.S. FISH COMMISSION
STEAMER ALBATROSS
Lieut. Comdr. J.L. Tanner U.S.N. Comdg.
February to April 1891
Compiled from the latest U. S. Hydrographic Office charts with additions by the U.S.F.C. Steamer Albatross.
Soundings represented thus 2246 are by the U.S.F.C. Str. "Albatross" 1888
" " " " " 1889
" " " " " 1891
Soundings represented thus 2246 are from other sources
100 fathom line shown thus
500 " " " "
1000 " " " "
2000 " " " "
P. Pebbles, co. coral, Gl. globigerina, M. mud, O. ooze, S. sand, T. rock, Stn. stones,
Gr. sprotte, G. ground, Fn. fine, Md. hard, Sft. soft, Rky. rocky, Brk. broken,
Bk. black, Rd. red, Gy. grey, Yl. yellow, Br. brown, Gn. dark, W. light
Wh. white.
GULF OF MEXICO
MEXICO
GUATEMALA
HONDURAS
SALVADOR
NICARAGUA
COSTA RICA
PANAMA
COLOMBIA
CARIBBEAN SEA
Gulf of Fonseca
Gulf of Nicoya
Gulf of Dulce
Gulf of Panama
GUAYMAS
Agiabampo
Topolobampo
Altata
MAZATLAN
San Blas
Banderas Bay
C. CORRIENTES
Manzanillo
Maruata
ACAPULCO
Petacalco Bay
P. Angeles
Salina Cruz
PERUANTEPEC
La Puerta
Champerico
S. Jose
Acajutla
La Libertad
Corinto
Realejo
C. Blanco
Nicoya
Herradura
Puntarenas
Golfito
Mariato Pt.
C. Mala
C. Corrientes
Choco Bay
Gorgona
Gallera Pt.
C. SAN FRANCISCO
C. San Lorenzo
Piedra
Cascal I.
Rinconcillo Bay
Roca Redonda
Roca Partida
Pearl Islands
Taboga I.
Taboguilla I.
Flamenco I.
Perico I.
Culebra Pt.
Panama
Chagres
Porto Bello
Limon Bay
Aspinwall
Navy Bay
Chiriqui Lagoon
Almirante
Bocas del Toro
Escudo de Veraguas
Pedro Gonzalez I.
Coiba I.
Montijo Bay
Parida I.
Rosario Bank
Roncador Bank
Serrana Bank
Quita Sueño Bank
Nicaragua Rise
Albatross Bank
Misteriosa Bank
Pedro Bank
Track of the U.S.F.C. Str. "Albatross" 1891
GALAPAGOS ISLANDS
(For Soundings around these Islands see Chart No. II)
Culpepper I.
Wenman I.
Abingdon I.
Bindloe I.
Albemarle I.
Narborough I.
Tower I.
Albemarle I.
Charles I.
Chatham I.
Hood I.
Barrington I.
Indefatigable I.
James I.
Duncan I.
Jervis I.
Bindloe I.
REVILLA GIGEDO ISLANDS
Roca Partida
SOCORRO
Roca Redonda
Roca Partida
Roca Redonda
Soccorro Bank
Clarion I.
Clarion Bank
Johnston Bank
Roca Redonda
Roca Partida
Roca Redonda
Roca Partida
Roca Redonda
Roca Partida

The following Publications of the Museum contain Reports on the Dredging Operations in charge of Alexander Agassiz, of the U. S. Fish Commission Steamer "Albatross," during 1891, Lieut. Commander Z. L. Tanner, U. S. N., Commanding.

Three Letters from ALEXANDER AGASSIZ to the Hon. Marshall McDonald, U. S. Commissioner of Fish and Fisheries, on the Dredging Operations of the "Albatross" in 1891. Bull. M. C. Z., Vol. XXI. No. 4. June, 1891. 16 pp.

I. A. AGASSIZ. On Calamocrinus Diomedæ, a new Stalked Crinoid from the Galapagos. Mem. M. C. Z., Vol. XVII. No. 2. January, 1892. 95 pp. 32 Plates.

II. A. AGASSIZ. General Sketch of the Expedition of the "Albatross," from February to May, 1891. Bull. M. C. Z., Vol. XXIII. No. 1. February, 1892. 89 pp. 22 Plates.

III. A. GOËS. Neusina Agassizi. Bull. M. C. Z., Vol. XXIII. No. 5. December, 1892. 4 pp. 1 Plate.

IV. H. LUDWIG. Vorläufiger Bericht über die erbeuteten Holothurien. Zeit. Anz., No. 420. 1893. Bull. M. C. Z., Vol. XXIV. No. 4. June, 1893. 10 pp.

V. GEO. P. MERRILL. The Rocks of the Galapagos. Bull. M. C. Z., Vol. XVI. No. 13. July, 1893. 3 pp.

VI. W. FAXON. Preliminary Descriptions of new Species of Crustacea. Bull. M. C. Z., Vol. XXIV. No. 7. August, 1893. 72 pp.

VII. S. H. SCUDDER. The Orthoptera of the Galapagos. Bull. M. C. Z., Vol. XXV. No. 1. September, 1893. 25 pp. 3 Plates.

VIII. W. SCHIMKÉWITSCH. The Pygnogonidæ. Bull. M. C. Z., Vol. XXV. No. 2. December, 1893. 17 pp. 2 Plates.

IX. W. McM. WOODWORTH. The Planarians. Bull. M. C. Z., Vol. XXV. No. 4. January, 1894. 4 pp. 1 Plate.

X. TH. STUDER. Note préliminaire sur les Alcyonaires. Bull. M. C. Z., Vol. XXV. No. 5. February, 1894. 17 pp.

XI. S. F. CLARKE. The Hydroids. Bull. M. C. Z., Vol. XXV. No. 6. February, 1894. 7 pp. 5 Plates.

XII. H. LUDWIG. The Holothurians. Mem. M. C. Z., Vol. XVII. No. 3. October 1894. 183 pp. 19 Plates.

XIII. R. BERGH. Die Opisthobranchien. Bull. M. C. Z., Vol. XXV. No. 10. October, 1894. 109 pp. 12 Plates.

XIV. A. ORTMANN. The Pelagic Schizopoda. Bull. M. C. Z., Vol. XXV. No. 8. September, 1894. 13 pp. 1 Plate.

XV. W. FAXON. The Crustacea. Mem. M. C. Z., Vol. XVIII. April, 1895. 292 pp. 67 Plates.

XVI. W. GIESBRECHT. Die Pelagischen Copepoden. Bull. M. C. Z., Vol. XXV. No. 12. April, 1895. 20 pp. 4 Plates.

XVII. C. H. TOWNSEND. The Birds of Cocos Island. Bull. M. C. Z., Vol. XXVII. No. 3. July, 1895. 8 pp. 2 Plates.

XVIII. C. HARTLAUB. Die Comatuliden. Bull. M. C. Z., Vol. XXVII. No. 4. August, 1895. 26 pp. 4 Plates.

XIX. G. W. MÜLLER. Die Ostracoden. Bull. M. C. Z., Vol. XXVII. No. 5. October, 1895. 10 pp. 3 Plates.

XX. A. GOËS. The Foraminifera. Bull. M. C. Z., Vol. XXIX. No. 1. February, 1896. 103 pp. 9 Plates.

XXI. O. MAAS. Die Medusen. Mem. M. C. Z., Vol. XXIII. No. 1. September, 1897. 92 pp. 15 Plates.

XXII. H. J. HANSEN. The Isopoda. Bull. M. C. Z., Vol. XXXI. No. 5. December, 1897. 38 pp. 6 Plates.

XXIII. A. AGASSIZ. Preliminary Report on the Echini. Bull. M. C. Z., Vol. XXXII. No. 5. June, 1898. 18 pp. 14 Plates.

XXIV. E. L. MARK. Preliminary Report on Branchiocerianthus urceolus. Bull. M. C. Z., Vol. XXXII. No. 8. August, 1898. 8 pp. 3 Plates.

XXV. C. F. LÜTKEN and TH. MORTENSEN. The Ophiuridæ. Mem. M. C. Z., Vol. XXIII. No. 2. November, 1899. 114 pp. 22 Plates and Chart.

XXVI. S. GARMAN. The Fishes. Mem. M. C. Z. Vol. XXIV. November, 1899. 426 pp. 97 Plates and Chart.

XXVII. W. McM. WOODWORTH. Preliminary Account of Planktonemertes Agassizii. Bull. M. C. Z., Vol. XXXV. No 1. July, 1899. 4 pp. 1 Plate.

XXVIII. L. STEJNEGER. Two new Lizards of the genus Anolis, from Cocos and Malpelo Islands. Bull. M. C. Z., Vol. XXXVI. No. 6. November, 1900. 6 pp. 1 Plate.

XXIX. W. E. HOYLE. The Cephalopoda. Bull. M. C. Z., Vol. XLIII. No. 1. March, 1904. 71 pp. 12 Plates.

XXX. H. V. WILSON. The Sponges. Mem. M. C. Z., Vol. XXX. No. 1. July, 1904. 164 pp. 26 Plates.

XXXI. R. VON LENDENFELD. The Radiating Organs of the Deep Sea Fishes. Mem. M. C. Z., Vol. XXX. No. 2. August, 1905. 48 pp. 11 Plates, 1 Chart.

XXXII. A. AGASSIZ. The Panamic Deep Sea Echini. Mem. M. C. Z., Vol. XXXI. November, 1904. 10, 243 pp. 112 Plates.

XXXIII. E. VON MARENZELLER. Stein-und Hydro-Korallen. Bull. M. C. Z., Vol. XLIII. No. 2. August, 1904. 16 pp. 3 Plates.

XXXIV. E. VON MARENZELLER. Lagisca Irritans, sp., nov., ein Symbiont von Hydrokorallen. Bull. M. C. Z., Vol. XLIII. No. 3. August, 1904. 6 pp. 1 Plate.

XXXV. H. LUDWIG. Asteroidea. Mem. M. C. Z., Vol. XXXII. July, 1905. 12, 292 pp. 35 Plates, 1 Chart.

PUBLICATIONS

OF THE

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